The
ENGINEERS' DIGEST

REVIEW OF ENGINEERING PROGRESS ABROAD

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"METAL PROGRESS," ***December, 1941—***

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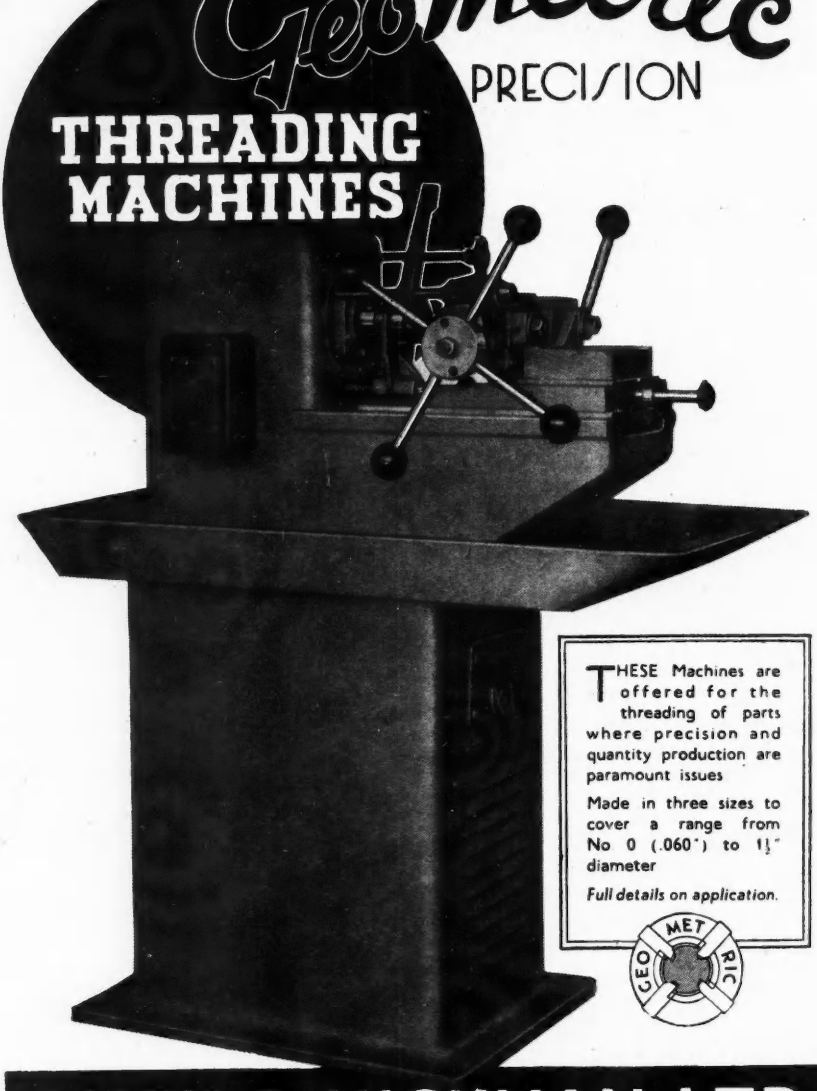

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SIMILARITY CONSIDERATIONS RELATING TO TURBINES AND COMPRESSORS

By E. ECKERT. (From *Luftfahrtforschung*, Vol. 18, No. 11, November, 1941, pp. 387-395).

Hydraulic Similarity.

To obtain similarity of flow of a gaseous medium in two machines, a number of dimensionless factors must apply equally to both machines. By nature these factors are the same whether the flow is through nozzles or around aerofoils. Thus we are justified by considering in Fig. 1 two aerofoils, I and II, around which the flow should be identical. The first condition is geometrical similarity, i.e., the ratio of wing thickness to chord must be equal, $d/t = d'/t'$. The same applies to the wing spans, b, if they cannot be considered as infinite. The geometrical similarity must be further extended to the roughness of the wing surfaces. If the mean elevation of surface irregularities is denoted by K, the respective ratios of K/t must be equal for the two wings.

The second condition to be satisfied is similarity of undisturbed flow at some considerable distance from the aerofoils, whereby the speeds Co and Co' are taken at points of corresponding location. If the peripheral velocity at corresponding points is denoted by C and C' respectively, the condition for similarity can be expressed by $C/Co = C'/Co'$. If the aerofoil itself is moving at a velocity u, say perpendicular to the undisturbed flow, the additional condition for similarity is given by $u/Co = u'/Co'$. The last mentioned condition for similarity is well known as Reynold's Number, or $Co.t/\nu = Co't'/\nu'$ (ν is the kinematic viscosity of the fluid).

The above conditions relate to incompressible fluids, or ideal gases, and also the following considerations will be confined to these. A great simplification is achieved by this without essentially impairing the validity of the conclusions as the flow is generally subsonic. In centrifugal machines, working near the saturation point of steam, this, however, may be different, since for varying density the speeds become variable with the temperature. In this case the similarity must be extended also to the absolute temperatures at similar locations.

Two other factors are necessary to cover the case for similarity of flow of gaseous mediums ; these are the Mach number, $Ma = Co/Cs$, (Cs is the velocity of sound), and the Prandtl Number $Pr = \nu/a$ (a being the thermal conductivity). The latter, for an ideal gas, is dependent on the number of atoms in a molecule, and so is the adiabatic exponent $x = Cp/Cv$. For similarity of flow either x or the Prandtl munber must be the same for the two fluids.

When all the above conditions are satisfied, we have similarity of flow and consequently the effects of flow will be the same for the two cases. Thus the pressure distribution around the two aerofoils will be the same and the forces caused by the flow similar. In general two forces are acting upon the aerofoil : a force transversed to the direction of flow, termed the lift A, and a resistance termed drag, W. These can be expressed by two coefficients, for lift and drag respectively,

$$C_A = \frac{A}{qF} \text{ and } C_W = \frac{W}{qF},$$

where q is the dynamic pressure and F an arbitrary area (say $t \times b$). The values of the coefficients for the two aerofoils must be the same.

The equations can be written in a more general form, thus :

$$C_A = f(d/t, C/Co, u/Co, T/To, Re, Ma, Pr) \quad (1)$$

$$\text{and } C_W = g(d/t, C/Co, u/Co, T/To, Re, Ma, Pr) \quad (2)$$

Each of the factors in equation (1) or (2) can be replaced, the condition of such a transformation being that the number of factors remains unchanged. If we calculate, for instance, from equation (2) the speed ratio u/Co and substitute it into equation (1), we get the relation :

$$C_A = f(d/t, C/Co, C_W, T/To, Re, Ma, Pr) \quad (3)$$

These similarity considerations will be now applied to a single stage centrifugal machine consisting of the stator, a, and the rotor, b, (Fig. 2). The multi-stage case is simply derived by ranging the stages together. The two machines to be considered should be geometrically similar. This similarity must apply inter alia also to the axial and radial gaps between a and b, and to the surface smoothness. For greatly reduced sizes this may lead to difficulties. However, the latter conditions need not to be strictly adhered to, as it is sufficient to keep the surface irregularities within the laminar boundary layer. The thickness of this layer is dependant on the Reynold's number. Thus, corresponding to every Reynold's number there is a definite surface smoothness beyond which no improvement is necessary.

It may be difficult also to keep the ratio of the radial gap to rotor diameter constant with decreasing size. A good idea of what can be regarded as manufacturing limit is conveyed by the standard bore and the respective shaft. The standard equation is :

$$i = 0.45 \sqrt[3]{d} + 0.001\, d \quad .. \quad (4)$$

where i is the clearance measured in μ-s and the shaft diameter in mms. Accordingly the same relationship applies to the allowable radial gaps.

For similarity of speeds the ratio C/u at entry must be the same. u is the circumferential speed, and the

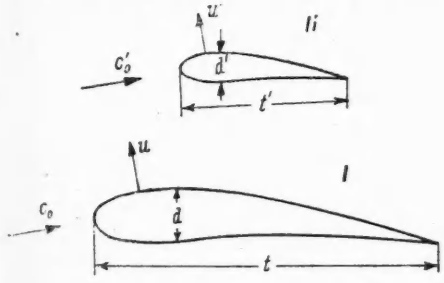

Fig. 1. Flow around two similar aerofoils.

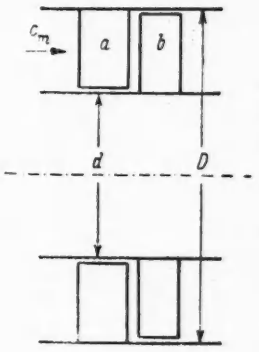

Fig. 2. Single stage centrifugal machine.

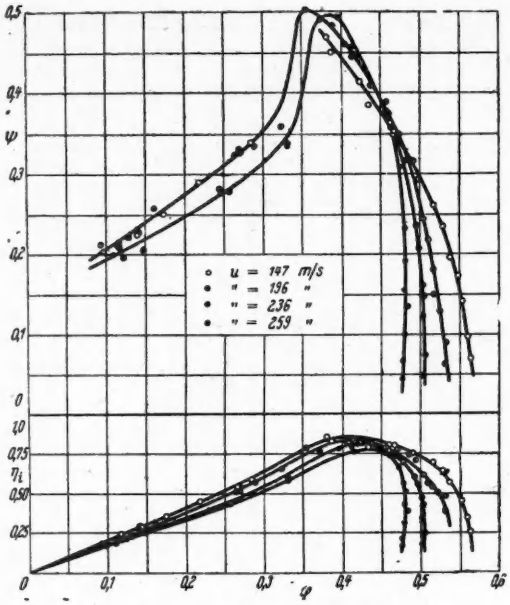

Fig. 3. Diagram of an axial supercharger.

velocity of flow, C_m, is the axial component of flow at the inlet, thus :

$$C_m = \frac{V}{\frac{D^2 \pi \delta}{4}} \quad .. \quad .. \quad (5)$$

V is the volumetric flow per unit time, and the area of flow $\frac{D^2\pi}{4}\delta = \frac{D^2\pi - d^2\pi}{4}$. $C_m/u = \varphi$ is called the coefficient of flow.

It was mentioned before that the temperatures at inlet must be also similar. If the effect of cooled members is disregarded and the condition of similarity of temperatures and speeds at entry satisfied, then for given geometrical similarity the flow through the machine is determined by φ, Re, Ma, Pr. If the corresponding value of these four coefficients for the two machines are the same, the flow will be in all details similar. Bearing losses are entirely neglected in this chapter, and will be dealt with separately later. The internal efficiency η_i of the machine (without bearing friction) is thus dependent on the above four coefficients.

Of special importance is the pressure coefficient, Ψ :

$$\Psi = h_{ad} / \frac{u^2}{2g} \quad .. \quad .. \quad (6)$$

It compares h_{ad}, the adiabatic heat drop available with the kinetic energy at the circumferencial speed u. For small pressure differences, Δp, of the front and rear of the machine $h_{ad} = \Delta p/\gamma$, for larger pressure differences $h_{ad} = \int dp/\gamma$, (γ = weight of unit volume of gas).

The relation in case of similarity is :

$$\Psi = f(\varphi, Re, Ma, Pr) \quad .. \quad .. \quad (7)$$

and the internal efficiency

$$\eta_i = g(\varphi, Re, Ma, Pr) \quad .. \quad .. \quad (8)$$

In equation (7) and (8) the coefficient of flow φ, is of greatest importance, and its magnitude will determine whether a transition of flow will occur at some point of the blade. Thus, one can write approximately :

$$\Psi = f(\varphi), \text{ and } \eta_i = g(\varphi) \quad .. \quad .. \quad (9)$$

for centrifugal machines working with incompressible media, and also for those with low speeds of flow and small pressure differences. For higher velocity of flow, Pr and Ma, too, enter into the picture. The influence of the Mach number can best be ascertained by making tests with the same machine at various r.p.m.'s and different velocities at inlet. As in such cases the change in Reynold's number is negligible, the dimensionless plotting of the test results shows directly the influence of Mach number. If this had no influence, such a graph would show one curve for all engine speeds. Figs. 3 and 5 give results of a radial supercharger, an axial supercharger, and two exhaust gas turbines. Fig. 3 was obtained from experiments made at the "Aerodynamische Versuchsanstalt," Gottingen (A. Betz: Jahrbuch, 1938, d. Deutch. Luftfahrtforshung, Part II., p. 183), Fig. 4 was prepared by Daimler-Benz (K. Kollmann : Luftwissen, Vol. 7, 1940, p. 54), and Fig. 5 is based on experiments of the Junkers works. It should be noted that in radial superchargers appreciable changes in pressure can occur if the relative velocity of flow, w, is small, as can be seen from the equation :

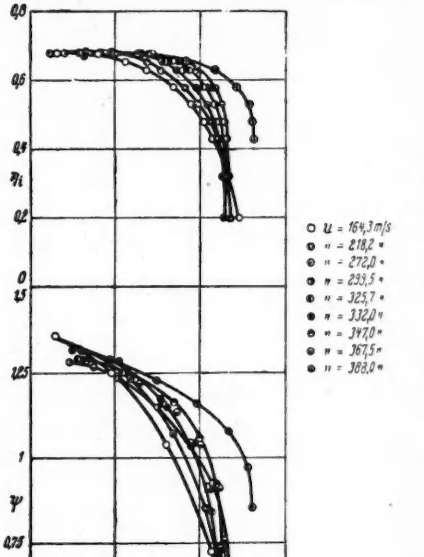

Fig. 4. Diagram of a radial supercharger to the aero engine DB 600.

$$\frac{dp}{\rho} + d\left(\frac{w^2}{2}\right) - d\left(\frac{u^2}{2}\right) = 0 \quad .. \quad (10)$$

The diagrams also show that the efficiency is much more influenced by the Mach number than by the pressure coefficient. Figs. 3 and 4 give values for internal efficiencies, while Fig. 5 shows the efficiency including the losses through bearing friction.

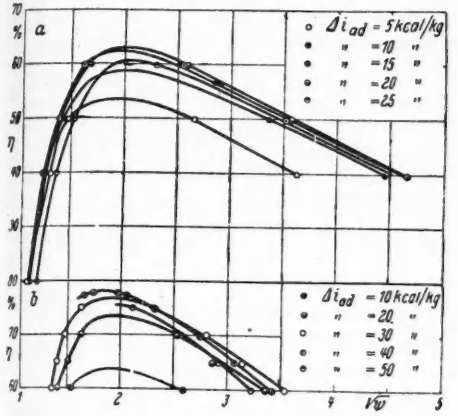

Fig. 5. Diagram of two exhaust superchargers to the Jumo 207 aero engine. a = Impulse turbine; b = Reaction turbine; Δi_{ad} = Adiabatic heat drop consumed.

In place of the coefficient of flow, the specific speed is used very often. This is obtained from φ and Ψ by framing the expression $\frac{\sqrt{\varphi}}{\sqrt[4]{\Psi^3}}$, which from equations (5) and (6) and $u = \pi Dn$, gives

$$\frac{\sqrt{\varphi}}{\sqrt[4]{\Psi^3}} = \sqrt{\frac{\pi\sqrt{2}}{\delta}} \cdot \frac{n\sqrt{v}}{\sqrt[4]{(g\,h_{ad})^3}} \quad .. \quad (11)$$

In this expression δ is constant and so is g and hence the specific speed of the machine is $n_s = \frac{n\sqrt{v}}{\sqrt[4]{h_{ad}^3}}$.

However, this expression is not a dimensionless quantity, neither has it dimensions of speed. The specific speed is equal to the numerical value of the r.p.m. of a machine which consumes unit volume of fluid at an adiabatic heat drop of unity. Again for approximate similarity one can write:

$$\Psi = f(n_s),\ \eta_i = g(n_s) \quad (12)$$

It should be mentioned that equations (7) and (8) of absolute validity, being derived from the general theory of similarity. They can be, therefore, applied without verification by tests. The equations for approximate similarity, however, should be always checked by experiments.

Similarity of Stressing.

The considerations discussed in the previous chapter will be useful for determining the efficiency, i.e., the fuel consumption of the engine. For aircraft engines, however, to obtain a low weight/power ratio is of equal importance. For a minimum value of this ratio all parts should be stressed to maximum permissible values. In centrifugal machines the rotating parts constitute the heaviest parts, and therefore, the condition of similarity of these parts under the action of centrifugal and elastic forces will be investigated.

Provided that Hook's law is valid for the materials to be compared, a similarity of stress distribution exists in two geometrically similar parts, under the action of inertia forces, if two corresponding factors are the same for both parts. These factors are: Poisson's ratio, m, and the Cauchy number, $Ca = \frac{v^2}{E/\rho}$, where v is the speed of the rotating parts at some datum point, E is Young's modulus, and ρ is the density of the material. The stress σ can be made dimensionless by dividing it by ρv^2. The general relation of similarity for geometrically similar parts is then:

$$\frac{\sigma}{\rho v^2} = f\left(\frac{v^2}{E/\rho},\ m\right) \quad .. \quad .. \quad (13)$$

As Poisson's ratio has values very nearly the same for all metals, it can be neglected altogether.

The dimensionless quantity $\frac{\sigma}{\rho v^2}$ must be constant also for the critical value of stress due to oscillations set up by periodic forces. Hence if the speed at which critical stress may occur is v_{crit}, equation (13) can be rewritten.

$$\frac{\sigma}{\rho v^2} = f\left(\frac{v}{v_{crit}},\ m\right) \quad .. \quad .. \quad (14)$$

The influence of $\frac{v}{v_{crit}}$ is noticeable within a certain speed range only, close to the critical speed. Beyond this speed range the dimensionless quantity $\frac{\sigma}{\rho v^2}$ is a function of Poisson's ratio only.

$$\frac{\sigma}{\rho v^2} = f(m) \quad .. \quad .. \quad (15)$$

It is practical to substitute in place of v the peripheral speed u, and equation (13) then states that the stresses in two similar rotors but of the same material are equal if the peripheral speeds are the same. This also means that for both rotors u_{crit} has the same value. However, according to $n_{crit} = \frac{u_{crit}}{D\pi}$, the critical engine speed is smaller for the larger rotor.

For rotors made of different material but having equal Poisson's ratio the maximum peripheral speed is determined according to equation (15) (not in the critical range). This is then the reason why rotating parts of duralumin, electron, and heat treated steels have approximately the same maximum permissible peripheral speed, in spite of the much higher allowable stress of steel, as compared to light metals.

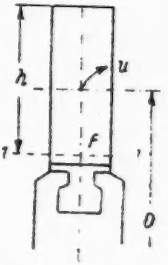

Fig. 6. Turbine blade.

Another case of similarity exists with parts stressed only in tension, and it will be seen that an approximate constancy of

stress can be maintained. This will be illustrated on a turbine blading, shown in Fig. 6, which has a cross sectional area, F, constant over the height h. Section 1-1 of the blade is under tension due to the centrifugal force $P = \rho F.h. \frac{2u^2}{D}$. If now the stress is constant over the cross section, we have $\sigma = \frac{P}{F} = \rho \frac{2h}{D} u^2$ and hence :

$$\frac{\sigma}{\rho u^2} = \frac{2h}{D} \quad .. \quad .. \quad (16)$$

From this equation it is apparent that the magnitude of stress is independent of the cross sectional area F. The constancy of stress at any distance from the axis is important for rotors having minimum weight. The thickness of such a disc is given by

$$s/s_a = e^{\frac{\rho u^2}{2\sigma}\left(1-\frac{r^2}{R^2}\right)} \quad .. \quad .. \quad (17)$$

in which 2s is the thickness at a distance r from the axis, $2s_a$ the thickness of the disc at the outer radius R. Fig. 7 shows the meridional cross section of such discs for various values of $\frac{\sigma}{\rho u^2}$. In the technical literature σ/γ is often written in place of σ/ρ. The ratio σ/γ, stress to specific weight, has the dimension of a length. It has been mentioned above that σ/ρ is almost constant for steel and light metals alike. Thus σ/γ has a value of about 10 kilometres. With σ/γ fixed, to every value of $\frac{\sigma}{\rho u^2}$ there is a definite value of u. In Fig. 7 the values of u in the brackets are given for $\sigma/\gamma = 10$ km. Equation (17) indicates that with constant stress, the thickness of the discs is proportional to the thickness at the outer radius ; the latter depends upon the stress due to the centrifugal force. The centrifugal force acting on the blade produces a tensile stress, σ_1 which must not exceed the allowable maximum stress.

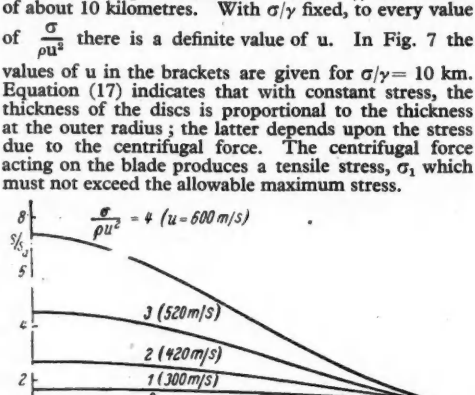

Fig. 7. Rotors of equal strength.

If the blade length is increased proportional to the rotor diameter without changing the cross sectional area of the blade, and the distance between the blades, it is sufficient to increase the radial dimensions of the rotor for similarity in radial direction only, whereby the axial dimensions remain unchanged. If now the peripheral velocities are the same, the stresses in both rotors will be constant and unchanged. Such an increase in scale (1:2) is shown in Fig. 8. The clearance between blades and the cross section of the blades must remain unchanged in order not to change the peripheral load at the outer diameter. The latter method is more favourable, therefore, from the weight point of view, but is applicable only to rotors loaded by pure tensile forces only. When, however, the force of flow increases appreciably, the bending load on the blade cannot be neglected any more and the increase in dimensions is accompanied by an increase of weight proportional to the third power of the diameter. This will be generally the case with centrifugal machinery for aircraft.

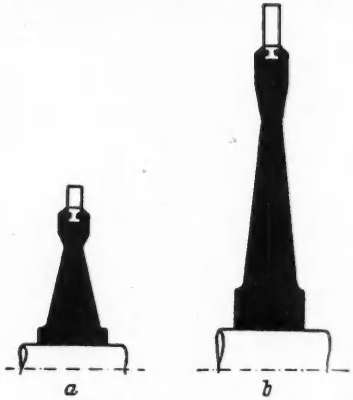

Fig. 8. Two rotors of equal strength with equal peripheral speed.

Consideration of Similarity Applied to Bearings.

The following investigation deals with journal bearings, as the phenomena in anti-friction bearing are far less clarified.

For two geometrically similar bearings the relation of pressures at corresponding points is given by

$$\frac{p}{\rho u^2/2} = f(R_e) = f\left(\frac{ud}{\nu}\right) \quad .. \quad .. \quad (18)$$

ρ is the density, ν the kinematic viscosity of the lubricant. The pressure, p, divided by the kinetic energy is dimensionless, the latter being dependent upon the peripheral speed, u, of the shaft. The diameter of the shaft, d, is used as parameter. For the oil film the inertia forces can be neglected compared with forces due to pressure and viscosity. By the theory of similarity equation (18) then becomes

$$\frac{p}{\rho u^2/2} \frac{ud}{\nu} = 2 \frac{pd}{\eta u} = \text{constant} \quad .. \quad (19)$$

whereby $\eta = \rho\nu$, called the dynamic viscosity.

Complying with a suggestion of ten Bosch, $\frac{pd}{\eta u}$ = Gü is called the Gümbel number.

The flow through two geometrically similar bearings is similar if the Gümbel number has the same numerical value for both bearings. The displacement of the shaft in the bearing, or to what it amounts to, the minimum thickness of the oil film, ho, in relation to d must be a function of the Gümbel number : $ho/d = f(Gu)$.

So far it was assumed that the properties of the lubricant remain unchanged with variation in temperature. This, however, does not hold good always, and for an exact similarity the variation of viscosity must be taken into account. Thus, new characteristics must be added to the already existing ones. The dependence of viscosity on the temperature must be such as to allow similarity in both bearings simultaneously. This is satisfied, for instance, by expressions containing the temperature ϑ as ϑ^n or $e^{-\vartheta}$. Thus one can write $\eta = \eta_0\ \vartheta^n$ or $\eta = \eta_0\ e^{-\vartheta}$, whereby the zero point from which the temperature is measured, and at which the viscosity is η_0, can be chosen arbitrarily. There is no Mach number in this case, as the density of oil is practically constant; instead, the heat due to internal friction has to be considered. A new number can be formed for this purpose, in which ϑ is the temperature difference which is impressed on the oil film by the boundary conditions: $\frac{\eta u^2}{\lambda \vartheta}$. Herein λ is the heat conductivity of the oil. Many problems connected with exact similarity are not yet solved, but the method of approximate similarity, as expressed by equation (19), can be safely used up to a peripheral velocity of 30 m/sec.

The excess temperature caused by internal heat is of special interest for higher speeds. An approximate relation will be given to extend that of equation (19), the assumption made being that the properties of lubricant are the same for both cases. The heat Qr produced in the bearing is given as $Qr = \mu.P.u$, μ being the coefficient of friction, P the loading of the bearing, u the peripheral speed. Part of the heat Q1 passes into the bushing, $Q1 = \lambda \frac{F}{l} \vartheta$; λ is the heat conductivity of the oil, 1 some datum length, F some datum area and ϑ some datum excess temperature. Substituting for 1 the shaft diameter d, and expressing F by it: $Q1 = a_1.\lambda\, \vartheta\, d$. Here a_1 is dimensionless and constant for similar bearings. Another part of Qr is carried away with the oil stream by means of convection. Calling this Qk, it is given by: $Qk = a_2.c.w.F.\vartheta$. Again a_2 is a constant for similar bearings, c is the specific heat, w some datum velocity in the oilstream. If assuming a constant viscosity the pressure of the lubricant is such that Reynold's number remains constant, the velocity of oil is inversely proportional to the dimensions of the bearing. Thus $Qk = a_3.c. \frac{F}{l}. \vartheta$ or again introducing d as before, we get: $Qk = a_4.c.d.\vartheta$. The total amount of heat in the oil is $Q = Q1 + Qk = a_5.d.\vartheta$, which is conducted away. Compared with the produced heat Qr, the excess temperature $\vartheta = a_6.\mu. \frac{Pu}{d}$. The coefficient of friction, according to experiments by Rumpf, can be expressed as:

$$\mu = a + b\frac{\eta u}{pd} = a + b\frac{u\,d\,\eta}{P};$$

a and b are constants. Substituting this into the equation for the excess temperature, the final equation is

$$\vartheta = a'\frac{Pu}{d} + b'\,u^2$$

a' and b' are constant for similar bearings with the same lubricant.

If bearing and rotor are enlarged in geometrically similar proportion, the centrifugal force loading the bearing becomes

$$P = C\,\rho\,l^3\frac{u^2}{l} = C\,\rho\,l^2\,u^2,$$

where ρ is the density of the rotor material, l the datum length, and C a constant for similar rotors. Substituting P into Gümbel's number, the latter becomes $\frac{\rho\,u\,l}{\eta}$, which is of the form of Reynold's number. The larger the Gümbel number, the nearer is the bearing to its limiting load.

Summary.

From a consideration of all the above factors, the author concludes at some length that (especially for aircraft) an installation consisting of several turbine or supercharger units is to be preferred from the point of view of weight/power ratio to a single machine of equal output.

A ROTATING INDUCTION FURNACE

By F. W. Scott and T. L. Joseph, Assistant Professor and Professor of Metallurgy respectively. (From *Metals and Alloys*, Vol. 15, No. 3, March, 1942, pp. 414-419).

The contamination of molten slag by crucible refractories has been a major difficulty in laboratory studies of slag-metal reactions. This is particularly true of oxidized slags used at the comparatively high temperatures of the basic open-hearth furnace. The rotating liquid crucible described by Barrett, Holbrook, and Wood permits contact between slag and metal, but prevents the molten slag from coming in contact with the crucible refractory. Although this type of furnace presents some operational problems, it provides a promising means of studying slag-metal reactions.

Since the work of Barrett, Holbrook, and Wood the authors have built similar equipment and have further developed several features of experimental technique which greatly reduced the number of unsuccessful tests. Most failures were due to movement of the slag upward along the metal until it reached the refractory and was quickly absorbed. In the present paper, the equipment used over a period of three years to study slag-metal reactions, will be described.

Principle of the Liquid Crucible.

If a container, holding a liquid, is rotated about its vertical axis, the inner surface of the liquid assumes the shape of a paraboloid under the simultaneous action of centrifugal force and gravity. The internal dimensions of the rotating liquid crucible are dependent upon the diameter of the container and its speed of rotation.

By applying this principle to molten metal, it is possible to form a paraboloid of liquid steel that will act as a crucible in which slag may be introduced and melted. Due to the difference between the surface tension of molten steel and molten slag, the slag will normally remain within the cup of metal and will not come into contact with the crucible wall. In this way, the contamination of the slag by the crucible refractory is avoided.

When such a crucible, its rotating base, and the coils of a high frequency induction furnace are enclosed in a gas tight box, the furnace atmosphere can be controlled.

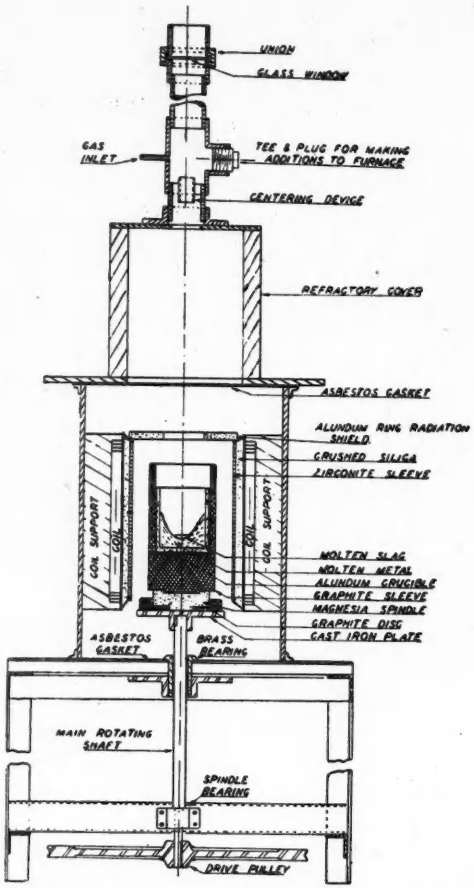

Fig. 1. Rotating crucible induction furnace.

With high frequency induction heating, the temperature can also be controlled within narrow limits. Fig. 1 shows the arrangement of the inductor coil, the rotating mechanism, and the gas tight box. The table for mounting the coil was constructed from 2 × ¼ in. angle iron with a $\frac{3}{16}$ in. steel plate for the top. This steel top was covered by a ½ in. transite board and a ¼ in. asbestos sheet. A hole 1¼ in. in diameter was cut in the centre of the top plate to accommodate the rotating shaft and a brass bearing. The bearing was held in place by a cast iron plate, bolted to the underside of the steel top. Forced grease lubrication prevented excessive wear and any mechanical difficulty at this point.

The vertical shaft, 1 in. diameter and 18 in. long, was reduced to ½ in. diameter at the spindle bearing which supported the entire weight of the rotating unit. This bearing was bolted to a heavy section of steel channel to give the rotating unit rigidity and to maintain alignment. This bearing is further removed from the furnace and gave no difficulty with normal lubrication. The drive pulley was keyed to the vertical shaft and connected to the electric motor by a round leather belt.

A cast iron plate, 5 in. in diameter, was fitted and keyed to the upper end of the rotating shaft. This served as a rotating table upon which the rotating crucible was mounted. A graphite disc to carry the magnesia spindle was bolted directly to this cast iron plate. This magnesia spindle supported a graphite sleeve which held the refractory crucible. A refractory at this point broke the connection between the two parts made of graphite, thus reducing the conduction of heat to the rotating mechanism. Particular care was necessary to make the upper surface of the disc perfectly flat and perpendicular to the shaft. Small deviations from the perpendicular were transmitted to the molten metal, causing sufficient distortion so that the slag was thrown out of the crucible by centrifugal force.

The inductor coil (6 in. outside diam., 5 in. inside diam., and 7 in. high) consisted of 35 turns of flattened copper tubing, wound on a mandrel. After the coil was wound the oil was removed by naphta, and the coil was thoroughly coated with bakelite. Each turn of the coil was separated from the other by a 1/16 in. layer of sheet mica with an inorganic binder.

The coil was mounted on one side of a transite-board box, 10 × 10 in. and 12 in. high. Electrical leads and cooling water connections were provided on the outside of the box. Angle iron was used to connect all corners of the box except those on the side containing the leads to the coil and it was found necessary to use transite in these corners to prevent arcing from the coil to the metal frame of the box.

The height of the box directly over the top of the furnace proper was extended because of the high temperature. The smaller upper section of the furnace housing is a monolithic structure, square on the outside and round in the centre. It was made of Lumnite cement and asbestos, reinforced with steel wire, and provided a cover over an open central area 5½ in. in

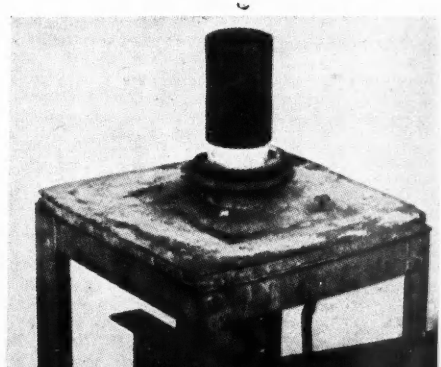

Fig. 2. Furnace base, magnesia spindle and rotating graphite cup to carry alundum crucible.

diameter. This central area was finally sealed off by a tube made of pipe fittings.

The melt was observed through a glass window at the top of this tube. A plug on the side of the tube was removed when the slag materials were introduced. A small section of pipe located just below this plug served as a centering device for charging. Nitrogen gas, containing approximately 0.5% oxygen, was admitted through a $\frac{1}{8}$ in. pipe opposite the plug and permitted to escape through a pipe in the top of the table (see Fig. 2). The rate of gas passage was controlled by means of a pinch clamp on a rubber hose, and positive pressure was maintained at all times to prevent an infiltration of air.

After the furnace was built, the coil was lined with refractory materials. A 1/16 in. sheet of mica which had an inorganic binder was placed next to the coil. The space between the mica and a zirconite sleeve next to the coil was packed with fine silica. Alundum cement was used to cover the fine silica and to seal the sleeve to the sheet mica.

As shown in Fig. 1, the alundum containing the molten metal, fitted snugly into a graphite sleeve standing on a magnesia spindle. To insure good electrical coupling, the clearance between the graphite sleeve and the zirconite lining was held within $\frac{1}{4}$ of an inch. This required good alignment in the vertical axis.

When the furnace had been assembled, and the alignment checked, it was sealed with silicate of soda and asbestos fibre made into a paste. Complete sealing was indicated by painting all corners and edges with soap solution which indicated leaks when gas pressure was maintained in the box.

Preparation of Refractory Crucibles and Spindles.

To procure the necessary refractory articles, commercially, in the sizes and types required would be very costly if they could be obtained at any price. The preparation of these articles in the shape, size, and of materials desired is essential in this type of research.

A means of preparing these refractory articles has been described by E. P. Barrett and W. F. Holbrook. The process involves the making of a mold and a core of graphite, and then packing refractory material into the space between them by means of a vibrator. The mechanical action of the vibrator produces a dense packing of the dry refractory.

When the form would take no more dry material, the mold was removed from the vibrator, and the refractory moistened by a solution of silicate of soda (0.5% solution) or by a solution of boric acid. The core could be then removed without the form losing its shape. After careful drying of the refractory, the mold and refractory were placed in an induction furnace, heated slowly to 1700 °C, and then cooled slowly. At this temperature, the material sintered sufficiently to form strong refractory articles, resistant to thermal shock.

Electrically fused alundum, 100 mesh, was found most suitable for the alundum articles. Pure magnesia, 100 mesh, was used for the magnesia articles. The silicate of soda solution was used to moisten the alundum refractory, and the boric acid solution to moisten the magnesia.

The zirconite sleeve was made in the split graphite mold shown in Fig. 3. The core was wrapped in two layers of brown paper to allow for the shrinkage. The split mold was wired together, and the dry refractory packed into the form on the vibrator. The packed dry refractory was moistened with a solution of silicate of soda. After drying, it was placed in the furnace, slowly heated and burned at 1600 °C. By the time the paper burned out, the refractory had taken a set. As the temperature rose, the wire melted, but the refractory

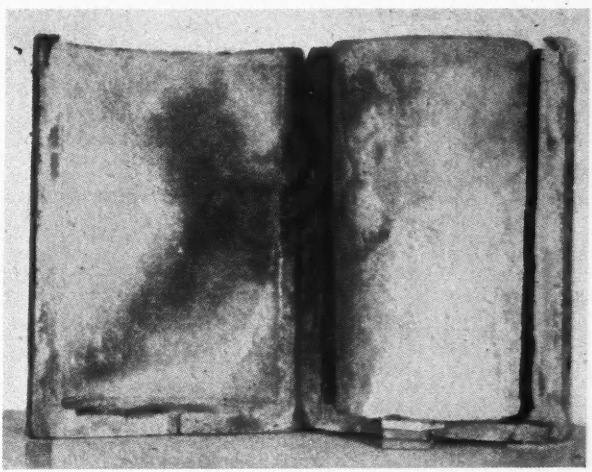

Fig. 3. Split graphite mould for making zirconite sleeve.

sleeve retained its shape, and finished $\frac{1}{8}$ to $\frac{3}{16}$ in. in thickness.

The time of heating required to form a ceramic bonded refractory was dependent upon the thickness of the section. Usually, the time could be approximated by watching the refractory article. When it shrunk enough to be free of the mold, and not enough to be deformed or undersize, the heating was complete.

Preparation of Slags.

It was found, after experiencing some difficulty, that pure powdered silica and pure calcined calcium carbonate could be briquetted after moistening by compressing in a steel cylinder. These cylindrical briquettes were dried and held at about 600 °C. until ready for use. Even though the powdered components were intimately mixed, the briquettes melted slowly and floated on the surface of the rotating molten steel before melting and had a tendency to move up the sides of the molten crucible until they contacted the alundum crucible and were rapidly absorbed. This resulted in fluxing and the formation of low melting constituents that soon produced a hole in the side wall of the crucible.

Experiments indicated that the melting of the briquette was facilitated by absorption of iron oxide from the metal. Further tests showed that the speed of melting could be increased by dropping small pieces of magnetite on the briquettes. In the procedure finally adopted, magnetite was added to the briquettes of all basicities. In most cases, 5% Fe_3O_4 was added to the lime-silica powder before briquetting.

The synthetic slag mixtures that were added to the molten steel containing appreciable amounts of manganese, contained manganese dioxide in a powdered form. After a few tests, however, it became apparent that magnetite was better than MnO_2 in forming a liquid slag. The addition of small amounts of oxide early in the test did not alter the composition of the slag at equilibrium. However, the fluid oxidizing slags, or those containing iron oxide, formed more readily and reduced the number of failure due to the contact between the slag and refractory crucible. Again this was most pronounced in the basic slags to which MnO_2 had been added. As a result, most of the tests in manganese series were made with slags containing iron oxide.

In tests made over metal deoxidized with silicon and carbon, the initial slag mixture contained 5% Fe_3O_4. These slags melted readily and the iron oxide was rapidly reduced from the slag, but not before the lime and silica had reacted to form liquid calcium silicates.

Removal of Slags from the Rotating Furnace.

To obtain data representing equilibrium conditions with respect to sulphur distribution between slag and metal, it was necessary to develop a technique by which the slags could be removed from the surface of the metal, at the existing temperature. Moreover, the slag, so removed, had to be chilled instantly to prevent any change in composition.

The first procedure for removing the molten slag was to chill it on the pointed end of a heavy cylinder of copper. This method was difficult to operate because the view into the crucible was obstructed by the copper cylinder. Moreover, if the cylinder was inserted too slowly, the tip was heated so hot that the slag would not chill completely and would drop off while being withdrawn from the furnace.

A better scheme was devised subsequently. The slag was removed by drawing it by suction into a graphite cup, where it was instantly chilled. As shown in Fig. 4, the small graphite cup was fitted snugly into the end of a ¾ in. diam. pipe. This pipe was connected to a vacuum pump by means of a length of rubber tubing. When the cup came into contact with or into very close proximity of the molten slag, it was instantly drawn into the cup, and chilled. The small diameter of the pipe and the cup allowed a good view of the slag during the operation, and as a result very few melts were lost because of inability to remove the slag and chill it to prevent any reaction with the metal.

Temperature Measurement.

The temperature of the bath was measured by means of an optical-pyrometer, sighted through the glass window at the top of the tube. The inside of the tube had been blackened with lamp black to avoid light reflection. The rotating crucible offered a rather difficult target, but the line where the slag and metal met was used to measure the temperature.

A platinum to platinum rhodium thermocouple was used to calibrate the optical-pyrometer. A large section of graphite electrode had two holes drilled in it, one to hold the silica tube containing the thermocouple and the other, a larger one, to serve as the target of the optical-pyrometer. Both holes were drilled to the same depth, were close together, and the bottom of each was believed to assume the same temperature when the graphite was heated. The graphite electrode section was placed in an electric resistance furnace. A tube made of pipe fittings, with a glass window, was placed over the hole in the graphite block, and clamped in line with it.

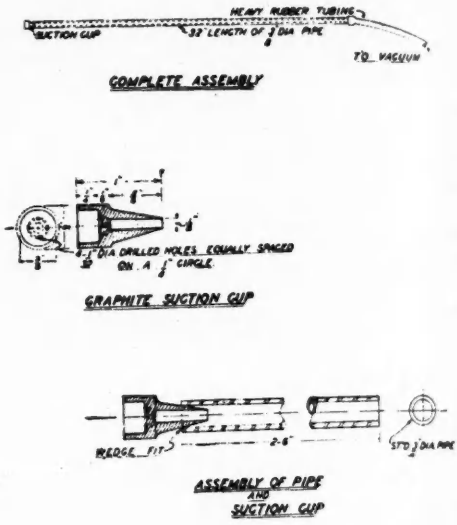

Fig. 4. Device for removing slags from rotating furnace.

The furnace was slowly heated, and the thermocouple readings were checked against simultaneous optical-pyrometer observations obtained by sighting on the closed end of the hole in the graphite block. Readings were taken up to 1550 °C. and the curve was extrapolated at 1700 °C.

SAVING FUEL IN GAS-HEATED FURNACE PLANTS

By WILHELM BESSE. (From *Stahl und Eisen,* Vol. 62, No. 8, February, 1942, pp. 156-160).

(*Continued from No.* 5, *p.* 195.)

By means of these gauges a very differential fuel consumption of the various units was observed, and it was found that the consumption of small and medium capacity units is very high compared with larger units. However, by checking the consumption carefully, some fuel saving could be achieved through more carefully controlled operation.

Reduction of Heat Losses during Standby Periods.

The plant was operated in two 8-hour shifts so that the standby period was 8 hours a day. Before actual work starts, the furnaces have to be heated up, thus further reducing the standby period. Nevertheless the temperature of the furnaces used to fall to 300 °C. This was partly due to inadequate heat insulation and partly to carelessness of the foundry man who left doors and flue dampers open. It was, therefore, strongly impressed upon them to take every measure to prevent excessive cooling off the furnace, and by keeping the doors and flue dampers closed the lowest temperature at the end of the standby period was now 600 °C. In

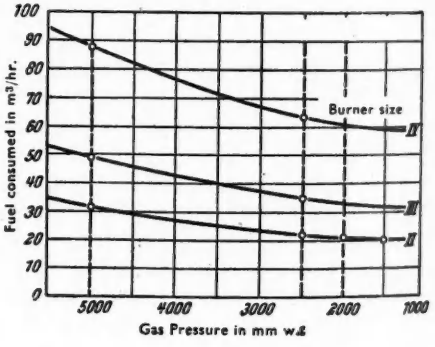

Fig. 1

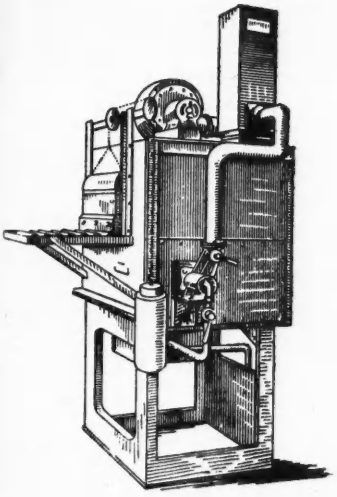

Fig. 2

addition the heat insulation of doors was improved upon and automatic sliding doors were installed. Apart from fuel saving, this also proved to assist in the handling of the work.

Two minor alterations consisted of (a) fitting valve locks to gas pipes so that they could not be opened more than is essential for proper combustion, and (b) the chimney cross-section was increased, calculated on the basis of volumens of gases taking part in combustion.

Re-Building of Furnaces.

As can be seen from the following few cases, very good results were obtained by re-building the furnaces and providing appropriate heat insulation. A small oven of 1.35×0.8 m² surface for reheating the bars of 400 mm. diameter was redesigned. The output of the furnace averaged 120-140 kg/hour. Originally it had a wall of fire-clay half a brick thick and a 6 mm. asbestos board. The air to the furnace was preheated only to 100 °C by a small regenerator. The hot air piping was not heat insulated. Two burners were located on the same side of the furnace and the gas consumption was 32 m³/100 kg. Next three more burners were installed, two on one side and one on the opposite side of the furnace so that the heat distribution became more uniform and the additional fuel consumption was found to be 27 m³/hour. To prevent excessive heat losses through the walls a fire brick half a brick thick and fire-clay 1/4 brick thick was used. The fire-clay was kept low so as to reduce the heat capacity of the walls. The regenerator, too, was replaced by a better type (Fig. 2) and the piping from regenerator to furnace was heat insulated. The new arrangement permits preheating to 300 °C. The fuel consumption, after all these alterations were completed, was only 25 m³/hour (21 m³/100 kg) so that the total saving in fuel amounts to 35%. Considering that the doors must be kept constantly open (large articles dealt with) and that the furnace is used only for special steels absorbing more heat than the usual type of work, the result must be regarded as most satisfactory. Following these results, all other furnaces for reheating bars were re-designed on a similar principle.

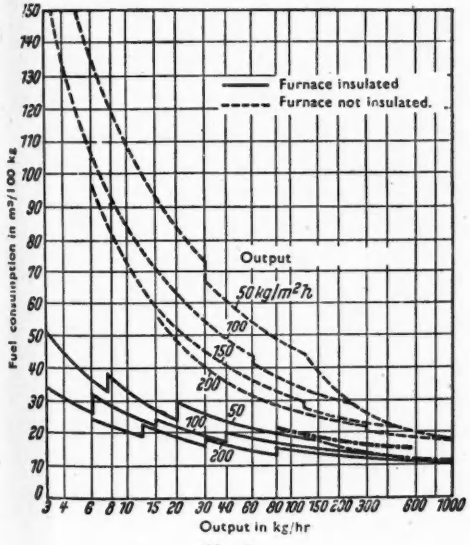

Fig. 3

Another furnace of medium capacity (1.1 m² heating surface and 210 kg/hr output) had originally a wall of fire-clay 1 brick thick and fire brick ½ brick thick. This was changed to fire brick half brick thick and fire-clay of the same thickness. The furnace arch was lowered by 120 mm. so as to form a main preheating zone. The air was preheated in a regenerator.

When put in commission the pressure in the furnace was too high and as the chimney was amply dimensioned the regenerator was suspected to be responsible for this. This was indeed the case and a small modification had to be executed. The operation of the furnace was then faultless. The gas consumption of the redesigned furnace was 21 m³/100 kg compared with the original figure of 31 m³/100 kg, that is a total saving of 32% was effected.

Fuel Consumption.

Reference figures for fuel consumption in dependance of furnace output were tabulated by W. Heiligenstaedt and are shown in Fig. 3. The dotted line shows the values obtained from our plant. As can be seen, they have slightly higher values than would be under optimum conditions, but the difference is only small and can be accounted for by the fact that the articles were twice heated.

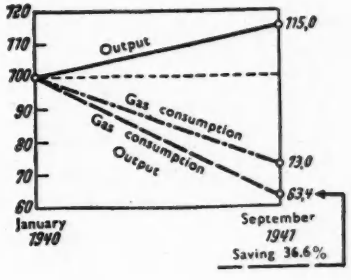

Fig. 4

Finally the output and fuel consumption of the plant for January, 1940, and September, 1941 respectively are compared with one another. Both the fuel consumption and output was made equal to 100 for January, 1940 in Fig. 9, and then the corresponding figures for September, 1941 become 73 and 115 respectively. Thus the total saving introduced by the change over to gas fuel, controlling of operation, increasing the air preheating temperature, improving heat insulation of furnace walls and doors, preventing excessive cooling during standby periods, etc., amounts to 36.6%. This saving compares very favourably with the first costs of re-building the plant, especially as there was a large increase in demand for special steel articles during recent years.

MACHINES, APPARATUS & TOOLS AT THE SWISS INDUSTRIES FAIR

By BRUNO HUMM. (From *Swiss Technics*, Vol. 21, No. 1, February, 1942, pp. 3-13).

Machines and Machine-Tools.

THE firm F. B. Hatebur, Basle, present a very interesting development with their fully automatic centreless grinding machines. All the movements are electrically and hydraulically controlled, as well as the traverse stroke and the movements of the diamond fixtures. The revolving speed of both the counter-pressure and traverse discs can be smoothly adjusted between 6 and 500 r.p.m. by means of one single device. The bearing pressure is also adjustable and may be read while the grinding is taking place. An original arrangement shows the moment when the machined part has reached the desired ground dimension. By means of an optical projection, the degree of accuracy reached is shown on an enlarged scale; an over or under grinding is thus prevented. If desired, the machine may be delivered with the most varied fittings, such as make it possible to use it as internal grinding machine, longitudinal grinder, &c. Special devices for mass production grinding are also available with the semi-automatic or fully automatic system.

G. Betz Sohn & Co., of Basle, again show this year their Suisse shaping machines in actual operation. Both models "320"=320 mm. stroke, and "450"=450 mm. stroke are fitted with the newest direct drive by means of V shaped belts. They are also built with a single disc drive.

The model "450" is remarkable for its sturdy and stable construction and is, therefore, suitable for heavy work. The big foundation plate and the strong attached supports which are so designed as to permit the passage of shafts up to 70 mm. diameter, give much stability to the machine. The carriage is fitted with liberal guides and its proportions are such as to enable it to withstand the heaviest strain. In opposition to other designs the carriage movement is effected by pulling and not by pushing. Automatic horizontal and vertical displacements of the work table of the machine are also provided. The design of the table support ensures running free from vibration in the machined part. This is a unique feature which, as well as the precise setting of the carriage for accurate work, without the necessity of disconnecting the driving gear, is protected by patent. The gear box is of the newest type and provides six speeds for this model. The gears run in an oil bath and speed shifting is very simply effected by means of a friction clutch and a clamp coupling.

The model "320" (Fig. 1) is of equally sturdy proportion, having regard to its stroke. The machine is fitted with either a tilting or a fixed table with automatic horizontal and vertical displacements. The gear box is similar to that of model "450," but giving only 4 speeds. This machine is also fitted with a hand operating device. Other great advantages of both machines are the reduced amount of power required for their running, as well as their being capable of adjustment without having to use spanners, a feature which greatly decreases the risk of defects.

A novelty developed during recent years, is the Micro-Maag instrument, shown in Fig. 2. This instrument was designed to take the place of plug gauges hitherto used when machining bores. The necessity for this arose from the fact that plug gauges cannot be used for measuring purposes, and also that they get worn out very quickly. But any success in this direction could be reached only by retaining the other practical advantages of the plug gauge. This is the case with the Micro-Maag Internal Guage. It is essentially

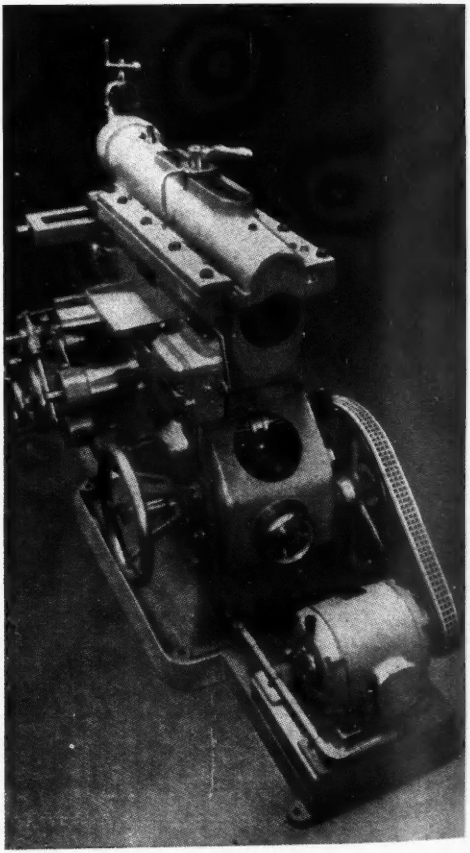

Fig. 1

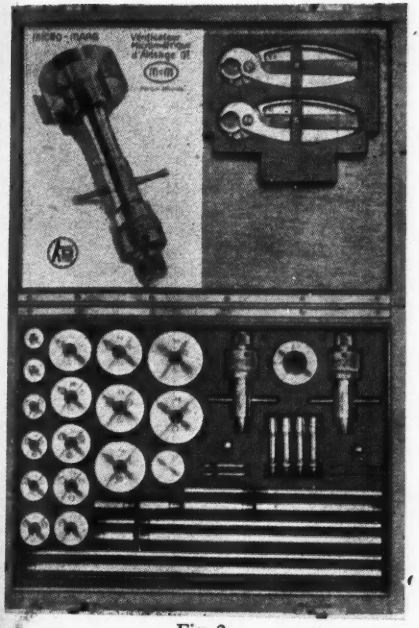

Fig. 2

an adjustable plug gauge which allows actual measuring to be undertaken to 1/1000 mm. and is so robust that it can be safely entrusted to any mechanic. The measuring bolts wear out very slowly since they never slide along the wall of the bore under pressure. Besides any loss in volume resulting through wear can be compensated by readjusting the measuring scale with respect to a standard gauge. The adjustable Micro-Maag internal gauge, therefore, outlasts dozens of the usual solid plug types, and the expense of acquiring it is insignificant in comparison with the continual costs entailed in inspecting and replacing ordinary plug gauges.

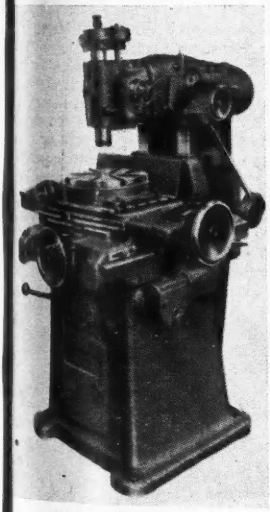

Fig. 3

Henri Hauser & Co., Ltd., Biel, have on exhibition, as specialities, precision jig boring machines, built from 100 × 100 to 600 × 400 mm. capacity.

The chief function of a precision jig boring machine is drilling of holes the axis of which is accurately defined by coordinates from a fixed point. A precision jig boring machine is, therefore, a combination of both a machine-tool and a measuring instrument. In order to make its utilisation possible in an ordinary workshop, it is necessary to design the measuring and dividing part with the same degree of accuracy as that of a measuring instrument, yet dimensioning them, as well as the tools, liberally enough to ensure a long life with constant precision (Fig. 3).

The Machines Dixi S.A., Le Locle, exhibit the following high precision machine-tools: An automatic circular grinding machine for cylindrical and conical work pieces. This machine is particularly suited for grinding large series of small parts. The grinding length can be adjusted between 1 and 120 mms., the distance between centres is 210 mms. at the maximum. The grinding spindle head has V-shaped guiding Dixi No. 2, and is provided with electric drive. The grinding wheel is carried in bearings on both sides. The spindle slides are adjusted by a precision feed mechanism, which allows a minimum adjustment of 0.0025 mm. per stroke of the table. The machine has an automatic stop device, but can be brought to rest also by hand. Automatic stopping is effected through an adjustable relay, adjustable between 12 to 150 secs. This relay operates a limit switch whose contact closes at the moment when the pawl is raised. By this arrangement, a certain number of polishing strokes can be made without any feed.

An automatic worm grinding machine. This robustly built high precision machine allows the best grinding wheels to be utilised to their full capacity. All control parts are protected inside the frame of the

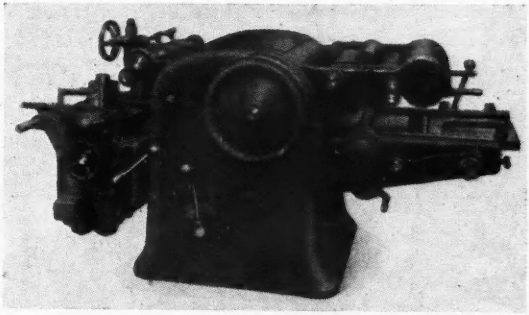

Fig. 4

machine; also the table guides are protected from dust. The grinding wheel is carried in a swivelling spindle head, which has a scale of degrees allowing it to be adjusted to the desired pitch angle. Feed is controlled by a precision guide spindle. The return stroke has four-fold acceleration. The setting of the grinding wheel is automatically effected, and the machine stops when the desired diameter has been reached. The work-piece is ground between centres and is driven by an operating catch. This operating catch is set on the work on to a special device arranged near the machine and is brought into proper position with respect to the worm. The machine is mounted on a water catch tray and fitted with a cooling pump.

A tool-maker's lathe. The Dixi tool-maker's lathe with V-guiding No. 4 is mounted on a pedestal. It serves for the most accurate turning of tools and work. The lathe is fitted with a jaw-gripping, universal chuck and centres. The thread-cutting device can be supplied for all pitches up to 3 mms. The principal dimensions of the lathe are: height of centres 110 mms., width

between centres 400 mms., bore for bars 20 mms., with clear opening of 16 mms. A perpetually variable gear allows regulation of the spindle speeds between 220 and 1980 r.p.m. The speed can be read off at any time from a revolution counter.

Muller, A. G., Brugg, Aargau, exhibit one of their motorised four-sides planing machines with a maximum planing width of 450 mms., already successfully employed in numerous works. Besides being of high capacity, this machine, with its high speed four-knife planing shaft and novel types of devices for pressing and guiding the wood, gives a neatly planed product. The same machine is also built for a maximum planing width of 610 mms., and for drive from shafting or by belt from a countershaft.

Amongst their exhibits the following deserve mentioning. A very useful universal wood-working machine intended primarily for small and medium sized carpenters' shops, repair shops or large industrial undertakings, railways, etc.; it performs five different classes of work, besides being extraordinarily light and quick to convert. This is the best type of machine for shops which have only limited space available. It is supplied in three sizes. In accordance with a widely expressed desire for a compactly built tenoning machine, but nevertheless, capable of large output and incorporating all the latest improvements, the firm has produced the motorised type CQML with four, five or six working shafts. The travelling table on to which the timber to be worked is attached either by means of a simple fixing device, or by an eccentric rapid-acting multi-grip device, moves on three rails on ball bearing rollers; it is consequently very easy to move and ensures accurate work (Figs. 4 and 5).

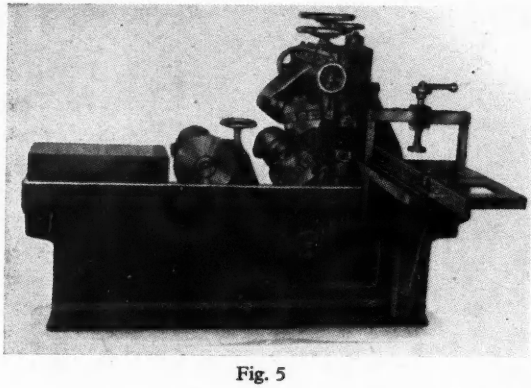

Fig. 5

The Machine Manufacture and Foundry, Netsal, A. G., Netsal, has developed original and excellent types of synthetic material presses which may be used in connection with accumulating plants as well as with individual drive. A 60-ton synthetic resin press combined with a special piston pump of new design is introduced at the exhibition, which may be given as a standard example of modern synthetic presses. It compares favourably with the various presses hitherto supplied from abroad, and is commendable for its first class workmanship. There is further to be seen a remarkable 10-ton eccentric press which is mass produced (Fig. 6).

Autogen Endress Ltd., Horgen, show for the 26th time their quality outfit for autogen working of metals. In view of the petrol shortage which has become acute,

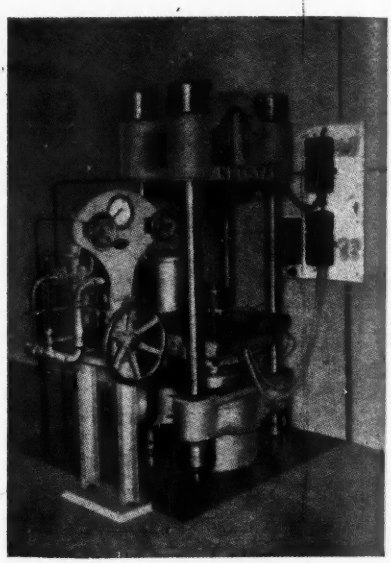

Fig. 6

the firm has made a most careful study of the problem of fuel substitutes, with excellent results. Several hundred cars, in Switzerland alone, have been fitted with the high pressure acetylene generator "Auto Endress." This generator is working on the excellent plunging contact principle, by which gas generation and stopping of gas production can be quickly and automatically secured. Thanks to the patented anti-freezing safety device, it has also proved successful for winter time operation (Fig. 7).

Apparatus and Instruments.

Decisive for the development of air-conditioning technique are the demands for steady conditions of air humidity in connection with the present-day high-grade manufacture of the most diverse kinds of natural and particularly substitute products in the textile, printing and paper trades, and in branches dealing with wood and leather. The design and construction of air-conditioning plants depends on the requirements and needs of each case, and accordingly different systems of apparatus and installations are built by the firm Paul Schenk, Ittigen, Berne. A novelty this year on the horizontal model is the provision of an air-regulating device. This consists of a plate-shaped disc, which is arranged in the suction stream of the fan, and can be

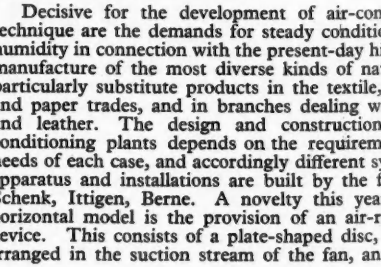

Fig. 7

adjusted as desired by means of a rod. In this way, the air and water introduced can be suited exactly to local requirements. Expensive installations become superfluous, since the Schenk humidifying and dehydrating apparatus are ready for service when connected to electric lighting or power circuits. The advantages of the unit air-conditioning apparatus consist essentially in their adaptability in practice, in the savings effected in building work and ducts, in the cheaper operating costs with good performance, ease of attendance, and supervision, little space required, as well as in the possibility of using them again should the building be converted.

In order to consider the needs of the moment, the Acquametro Wassermesserfabrik A.G., Basle, after having made thorough studies and carried out numerous practical tests, have brought out a series of new designs during the last year which are shown, for the first time, at the Industries Fair.

The blade-wheel and Woltman hot water meters are suitable for measuring boiler feed water, condensates, or service water at temperatures up to 95° C. and pressures of 16 atm. The revolutions of the measuring vane are transmitted to the counting mechanism by a stuffing box shaft. For higher temperatures and pressures these meters are fitted with a magnet coupling; in this way all stuffing box leakage is prevented.

Of great interest is the liquid meter with adjustable contact maker. In addition to the standard counting mechanism which works independently of the contact maker, a pointer is provided which can be set by push button. When the quantity, for which it is set, has passed through, it closes an electric circuit and releases an optical or acoustic signal or operates, according to need, a stop valve. The device can be provided for several contacts at a time. These meters are used where the quantity of flow is determined in advance, and has to be measured with very great accuracy. The contact maker relieves the operator in charge of the necessity of being perpetually on the look out.

Haenni and Cie, A.G., Jegenstrof, St. Gallen, manufactures instruments for measuring pressure, temperature and humidity in industrial services, and has recently delivered their millionth instrument. The firm does not go in for series production of measuring devices, but devotes itself to turning out single pieces of apparatus which are, so to say, especially suited for each branch of industry and for each particular purpose. All instruments are calibrated individually and are consequently trustworthy.

At this year's Fair, along with a great number of instruments of different types from the whole manufacturing programme, some novelties are shown. In order to meet the requirements of ventilating technique for measuring extremely small pressures, a fine draft gauge has been developed with a scale reading from 0 to 2 or 3 mm. W.G. By the new design it is also possible for such small pressure differences to be kept constant; also speeds in wind tunnels, even when of very small order, can be easily detected as a function of these pressure differences.

Opposed to this, a gauge for very high pressures, 0-7000 kg/cm², is also exhibited. Such gauges have lately been demanded by various branches of industry. In its works, the firm has the necessary testing equipment to allow such high-pressure instruments to be accurately calibrated.

A series of psychometers are shown this year for the first time: they are based on a new design, for which a patent has been applied for, and allow much more exact readings to be made of the degree of humidity. Along with the known instruments for determining the relative humidity, a so-called absolute psychometer allows the aquaeous vapour in grams/m³ of air to be determined, as well as the respective dew point. This instrument gives full information concerning the possibilities of ventilation. It assists essentially to decide the question whether ventilating may be done at all, without any risk of precipitation of aquaeous vapour.

RAPID ANALYSIS OF IRON ORE

By HUBERT KEMPF. (From *Stahl und Eisen*, Vol. 62, No. 7, February, 1942, pp. 136-140).

THE technique of production as well as the constancy of alloy composition demands from the chemist a rapid method of analysis to determine the exact composition of the ore, in particular the Manganese, Phosphorus, Sulphur, Silica and Carbon contents. Such is the case, as an example, in a Thomas-steel foundry, where an accurate analysis of the ore in the furnace is of immense help to the foundrymen in calculating the necessary charge and to draw up a heat balance. Of similarly great help is the analysis when the finished metal is poured into moulds.

A glance on the progress made in this line during the past few years will show that much has been achieved indeed. The older methods are all replaced by new ones; potentiometry, colorimetry, photometry and spectro-analysis are pushing into the foreground. The last mentioned method has been particularly successfully developed in the U.S.A., and with this method the time of analysis has been cut down to about 6 to 8 minutes for Manganese, Silica, Copper, Chromium, Nickel and Molybdenum. Difficulties are still encountered at present when applied to Carbon and Phosphorus, while for Sulphur, the method seems to be still more impracticable.

In Germany the rapid analysis method was developed on a different line altogether. The work was undertaken by the August-Thyssen-works, the basis of the development being the already known chemical methods, which have been developed to yield results suitable for a rapid analysis. Principally it was a question of organization, starting from sampling and finishing with the returning of the analysis result to the work, and cutting down the time to a bare minimum.

In the following the rapid analysis method will be described, as it is carried out in the August-Thyssen-works. It might be mentioned already at this stage that the complete analysis requires only 6 minutes, and together with sampling and preparing the sample for analysis 9 minutes. Just on 3 minutes are required for the transmission of sample and analysis results from workshop to laboratory by pneumatic transmission, this time, of course, depends upon the respective location of lab and workshop, and could be shortened by employing teleprinter or telephone communication.

Securing and Preparing the Sample.

With the aid of a small ladle some of the molten ore is secured from the jet when filling the ladles, and is then poured into a copper former which is held by a pair of pliers (Fig. 1). In this way the sample can be removed from the former immediately after quenching in cold water. The sample consists of a bar 100 mm. long and 7 mm. diameter, and has a contracted central portion to help breaking during the preparing phase. This consists of hammering in a steel mortar for 30 seconds, whence it is passed through a sieve of DIN 1171, No. 80 (0.075 mm. mash). The remainder is rejected. Tests have shown that the composition of the sample passing through the sieve was identical to the average of the fully prepared sample. About 5 g

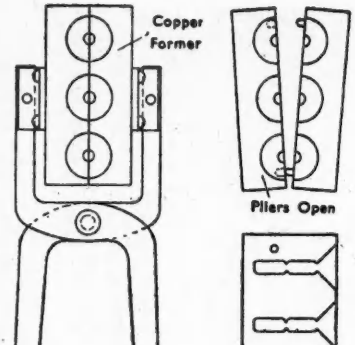

Fig. 1.
Former and holding pliers.

material is used for the analysis, and the time taken for securing and preparing the sample amounts to one and a half minutes.

Organization of Laboratory and Analysis.

The prepared sample is placed into a tin box and is sent to the lab via a pneumatic transmission system.

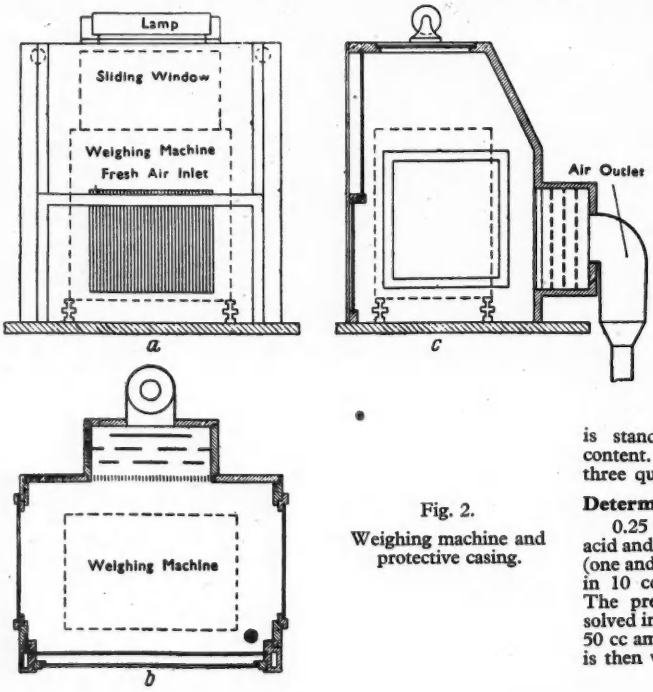

Fig. 2.
Weighing machine and protective casing.

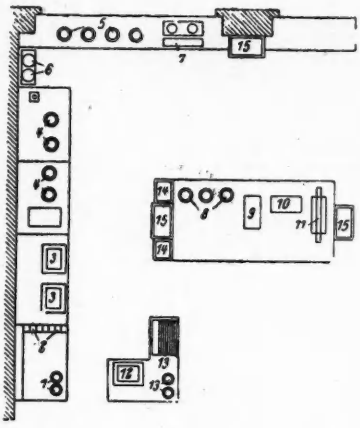

Fig. 3. Layout of Laboratory.
1. Pneumatic transmission, reception end
2. Storing place for samples
3. Weighing machines
4. Small elevators
5. Filtering set for phosphorus analysis
6. Titrating set for phosphorus analysis
7. Titrating set for Manganese analysis
8. Filtering set for Silica analysis
9. Electric oven for Silica analysis
10. Apparatus for Sulphur analysis 11. Mars-oven
12. Quick weighing machine
13. Teleprinter & pneumatic transmission, dispatching end 14. Cooling vessel
15. Sink

The laboratory is staffed by the chief chemist and 3 assistants. On receiving the sample, it is weighed out for the four tests respectively, i.e., Si, Mn, P and S analysis. Weighing takes about 30 to 35 seconds per test, two measurements being carried out simultaneously. The analyses are then carried out simultaneously and the result is transmitted to the works by telephone or teleprinter.

The weighing machines are fully enclosed and to prevent any leakage of steam, gas, etc., into the interior which might cause corrosion, a pressure somewhat higher than atmospheric is maintained inside the casing by pumping washed air into it. The arrangement of the balances is shown in Fig. 2.

The general arrangement of the lab is shown in Fig. 3, and it should be mentioned that certain precautions have to be taken to prevent explosion, as for the analysis of Si perochloric acid is used, which when in contact with organic substances might cause an explosion.

Determination of Mn Content.

The test is based on the persulphate-silvernitrate test according to H. P. Smith. 0.1 g of the sample is dissolved in 25 cc of nitric acid and 2 or 3 drops of peroxide, by heating over a bunsen flame (two and a half minutes). The solution is next oxidised by heating in 10 cc of silvernitrate (5 g/1) and 20 cc ammonium-persulphate (200 g/1); it is then cooled down to room temperature. (1 min.). After adding 100 cc of water and 3 cc of sodium chloride (12 g/1) the solution is titrated with 1/50 n sodium arsenate (3/4 mins.). The titrated solution is standardized against a solution of known Mn content. The total time taken for the test is four and three quarter minutes.

Determination of Phosphorus Content.

0.25 g of the sample is dissolved in 25 cc nitric acid and 3 to 5 drops of peroxide by heating in a crucible (one and three quarter mins.). The solution is oxidised in 10 cc potassium permanganate (25 g/1), (1 min.). The precipitate (manganese dioxide hydrate) is dissolved in 10 cc ammonium oxolate solution (40 g/1), and 50 cc ammonium molybdenum is added. The solution is then well shaken (1 min.). Filtration follows next;

for this purpose the crucible is rinsed twice with hot water and the filter 6 times (one and a quarter minutes). The residue is placed into a 300 cc crucible containing 10 cc sodium hydroxide (1 cc of the solution being equivalent to 0.001 g phosphorus) and 30 cc of water. When solution is complete another 100 cc of water is added as well as 2 drops of phenolphtalein solution, and is then titrated against a standardized solution of sulphuric acid of strength equivalent to the sodium hydroxide (1 min). The total time taken for the analysis is six and a quarter minutes.

Determination of Sulphur Content.

0.5 g of the sample is burnt in a mars oven at 1350° C. in the presence of current of oxygen (1 min.). The products of combustion (gas) is passed into a titrating vessel containing a solution of hydrogen peroxide (150 cc peroxide + 100 cc, 66% potassium sulphate + 4 drops of sulphuric acid + 15 l of water). To drive out all the carbonic acid, oxygen is bubbled through the solution for 3 minutes and the solution is then titrated against a standardized solution of sodium hydroxide. The end point of titration is potentiometrically determined (titration : 1/2 min.). The total time taken is five and a quarter minutes. The sulphur content is read off from a table. The standardization of sodium hydroxide is carried out in the usual manner. The apparatus used for this test is shown in Fig. 4.

To avoid loss of time by rinsing the gas conveying piping, the oxygen pipe is fitted with a four way cock, so that it is possible, when the mars oven is opened, to send a current of oxygen directly in the inlet tube to the titrating vessel where it bubbles through the solution. This also prevents wetting of the inside walls of the gas piping which would otherwise constitute an error.

The objection against this method, that namely three minutes are lost during bubbling oxygen through the solution if a potentiometric end point determination is used, constitutes in reality no loss at all, since the chemist can meanwhile carry out an estimation of carbon content.

Determination of Silica Content.

1 g of the sample is decomposed by 25 cc, 66% per chloric acid solution (free from silica acid) and is heated over a bunsen burner. The strength of the perchloric acid has to be carefully adhered to, as a stronger solution would cause too rapid a reaction with a danger of fuming, while a weaker solution would considerably prolong the duration of the test.

The beginning of the reaction is accompanied by violent foaming and, therefore, when the reaction is over, it is boiled for a few more seconds and is well shaken in the test tube to remove all particles adhering

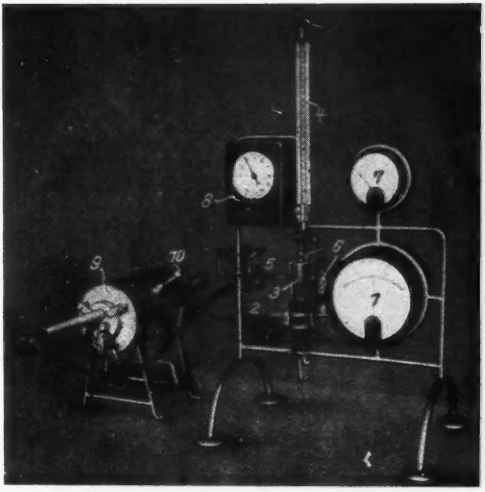

Fig. 4. Apparatus for Sulphur analysis.

1. Galvanometer
2. Adjustable resistance :
3. Absorbtion and Titrating vessel with admission piping
4. Burette
5. Four-way cock
6. Electrode
7. Thermometer
8. Micro-chronometer
9. Oven
10. Thermo element

to the glass wall and not yet in solution (2 mins.). At the same time to prevent further foaming 100 cc of water is added. This is then filtered by using a 1 cm thick filter material. The test tube is rinsed with water, the filter twice with hot perchloric acid and 3 times with hot water (1 min.). The filter together with the residue is now placed into a platinum crucible and is burnt in an electric oven to ash in oxygen atmosphere (2 mins.). The ash is carefully weighed on a weighing machine (3/4 mins.), and the % Si content can then be read off from a table. The total time for this process is 6 and a quarter minutes.

The results of the rapid analysis method were carefully checked by standard methods for some time. Table 1 shows comparative results from which it is evident that in no case is the discrepancy of a higher order than the error involved in the measurements. Therefore, the method can be regarded with confidence as a reliable one, and is of great assistance to modern high speed production.

TABLE 1

Test	% Mn		% P		% Si		% S	
	Standard analysis	Rapid	Standard analysis	Rapid	Standard analysis	Rapid	Standard analysis	Rapid-
1	0.83	0.84	2.00	2.00	0.37	0.38	0.069	0.069
2	0.70	0.71	2.06	2.08	0.40	0.40	0.064	0.063
3	0.85	0.85	2.00	1.96	0.37	0.37	0.073	0.072
4	0.71	0.71	2.06	2.04	0.39	0.40	0.065	0.065
5	0.84	0.85	2.02	2.00	0.37	0.38	0.075	0.073
6	0.70	0.71	2.08	2.08	0.38	0.39	0.064	0.063
7	0.84	0.85	2.02	2.00	0.33	0.34	0.072	0.071
8	0.69	0.69	2.08	2.08	0.37	0.37	0.065	0.064
9	0.82	0.82	2.02	2.04	0.34	0.35	0.070	0.069
10	0.70	0.69	2.08	2.08	0.36	0.37	0.065	0.065

OCTANE NUMBER AND MULTI-CYLINDER ENGINES

By A. W. SCHMIDT. (From *A.T.Z., Automobiltechnische Zeitschrift*, Vol. 45, No. 2, January, 1942, pp. 26-31).

RECENT publications on the question of detonation unanimously agree that octane number measurement—which is the sole universally-adopted test for fuel characteristics with regard to detonation—does not satisfy practical requirements: This method is incapable of giving results in agreement with detonation experienced in practice in multi-cylinder engines.

The problem involved is not that of accuracy of measurements, or sharp specification of test conditions, these have been adequately improved and developed, but it appears that octane number determination does not, in general, embrace the phenomenon of detonation in multi-cylinder engines.

In the laboratories of the technical college at Munich, comprehensive experiments were carried out to establish a relationship between engine and fuel, and electro-acoustical detonation measurements were made on multi-cylinder engines with far-reaching results which are described in the following.

One of the most striking observations was that only very rarely is detonation taking place in all cylinders simultaneously, and, as a rule, detonation is confined to some cylinders only while others are characterised by smooth running at the same time. A typical oscillograph showing this is reproduced in Fig. 1.

The test was started by adjusting the engine so that there was no detonating combustion. Then, by altering the ignition, detonation was provoked which, though not yet audible by the human ear, was recorded by the oscillograph. This state does not yet represent detonating operation of the whole of the engine, but only of one of the cylinders, of cylinder 4 in this particular case. On further promoting detonation it can be seen that it is still only this cylinder in which detonation takes place, although in cylinder 3 combustion is almost detonating. Finally, by still further increasing detonation, the picture shows that again it is cylinder 4 which is mainly responsible for detonation, to a lesser degree detonation is taking place in cylinder 2, while there is no further change produced in cylinder 3.

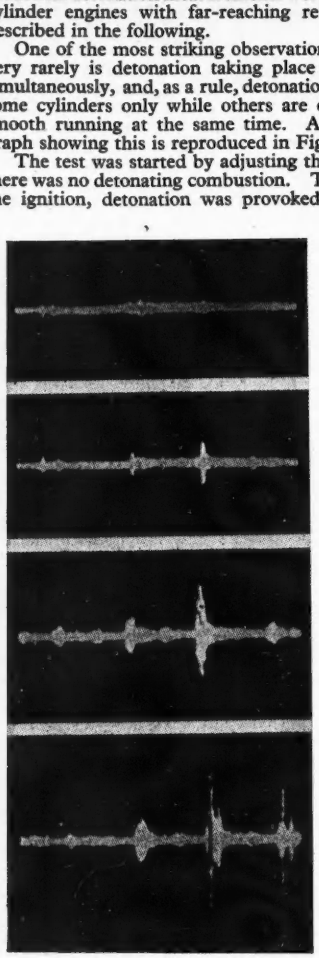

Fig. 1

Oscillograph of a 4-cyl. engine. Order of ignition: 1, 3, 4, 2.

(1) Smooth operation,

(2) Detonation starts (not audible),

(3) Moderate Knocking,

(4) Violent Knocking.

This experiment brings out clearly the differential behaviour of the same fuel in the different cylinders of the same engine. For this reason it cannot be attributed to the fuel characteristics alone, much rather it can be expected that detonation in cylinder 4, and smooth operation of cylinder 1, is caused by factors inherent to the individual cylinders.

Subsequently, a large number of experiments was carried out on various engines on the test bench as well as under actual running conditions, all of which have borne out the fact that not all cylinders are prone to detonation under otherwise identical conditions.

If this phenomenon is considered from the point of view of fuel characteristics, then one arrives at the conclusion that the fuel in the individual cylinders must be exposed to totally different operating conditions. The question arises, therefore:

Is it possible to determine fuel characteristics universally valid for multi-cylinder engines by the usual test methods, using single cylinder C.F.R. or I.G. (Germany) engines?

Before a satisfactory reply could be given to this question, the reason for the different operating conditions in the individual cylinders had to be carefully investigated. These investigations were carried out in the laboratories of the technical college on a popular four-cylinder engine.

Two constructional details were investigated first, which were known to have some influence upon detonation and to vary with the individual cylinders; these were the compression ratio and the point of ignition.

On carefully checking the compression ratio of each cylinder the following figures were obtained.

TABLE I.

Cylinder ..	1	2	3	4
Compression ratio	6.08:1	6.05:1	6.20:1	6.14-1

Cylinder 3 and 4 thus show a higher compression ratio than cylinder 1 or 2. The differences are, however, so small that they cannot affect detonation to a considerable extent.

The re-checking of ignition advance gave the following figures:

TABLE II.

Cylinder	1	2	3	4
Ignition advance degree before I.D.C. ..	27.4	28.9	30.8	29.8

Here, too, small variations were found, and it is again cylinder 3 and 4 which show the greatest ignition advance. The co-effect of these two factors may then be responsible for a more pronounced detonation in cylinders 3 and 4 than in cylinders 1 and 2.

Following this, detonation measurements were made, using four grades of fuels, marked A, B, C and D respectively. Although they were supposed to be of the same Octane number, small differences were found—viz. :

A = O.N. 74,
B = O.N. 75,
C = O.N. 72,
D = O.N. 73.

The electro-acoustical oscillograph is shown in Fig. 2. On the basis of the above mentioned discrepancies it was expected that cylinders 3 and 4 should show most violent detonation, and at first glance, this seems to be substantiated by the figure. It can be seen, however, that with fuel A, in the first cycle cylinder 3 detonates only while in the other two instances smooth running is recorded.

With fuel B, in the first cycle cylinders 3 and 4 show detonation, in the rest of the cycles only cylinder 4.

In contrast to this when fuel C is used, cylinder 3 shows detonation in two of the cycles and cylinder 4 in the third case.

Unexpectedly, with fuel D, cylinder 1 reveals detonation in the first and third cycle and cylinder 3 in the second cycle.

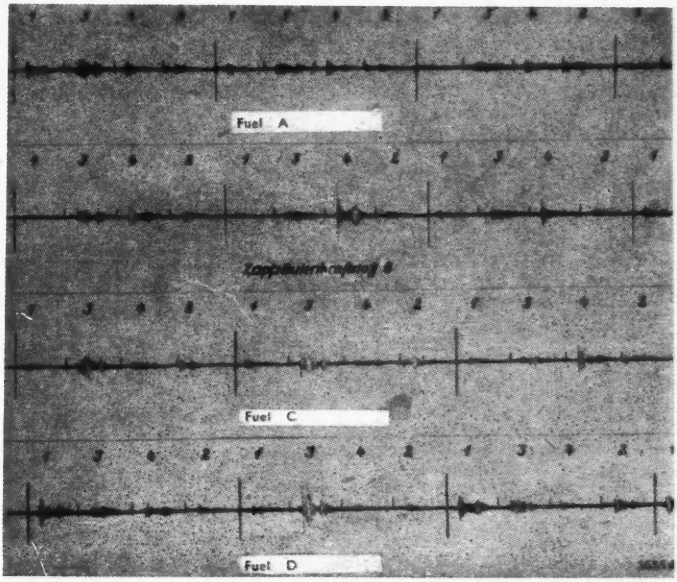

Fig. 2. Detonation under normal running conditions.

It is well illustrated by the oscillograph that cylinders 3 and 4 are most prone to detonation, but at the same time it also shows that other factors too, must be considered since in some cases, when there is no detonation in cylinder 3 and 4, their places are taken by either cylinder 1 or 2, which otherwise show little inclination to detonating combustion.

The search for other reasons for detonation has lead to the examination of the effect of fuel distribution between the individual cylinders with the following results.

After the engine was warmed up to normal operating temperature by running it for a short time, the ignition was interrupted and the engine was driven at normal speed by a separate motor connected to the shaft. It was now possible to re-collect the fuel reaching each cylinder partly by condensers and partly by absorption of the fuel by activated carbon. Normal operation temperature could be maintained by the frictional heat developed, and so steady conditions were maintained throughout the test. Each cylinder was, of course, fitted with a separate condenser plant, providing thus the means to compare fuel consumption of each cylinder.

The first series of tests was conducted by using pure petrol of O.N. 64, Table III. showing the percentage distribution as well as the O.N. determined after condensation for each portion separately.

TABLE III.

Cylinder	1	2	3	4
Quantity %	19	23	32	25
O.N.	65	63	65	64

The results show considerable variation in the fuel quantities reaching the cylinders. It was also thought that the quantity of air charge would disclose considerable variation, and therefore, this point was investigated too, with the following result :

TABLE IV.

Cylinder	1	2	3	4
Air charge/cyl./min. ..	149	150	153	153

from which it becomes apparent that, at least at this speed (800 r.p.m.), no appreciable differences in the air charge are encountered, and that the mixture strength is, therefore, only subjected to variation owing to the differential fuel charge.

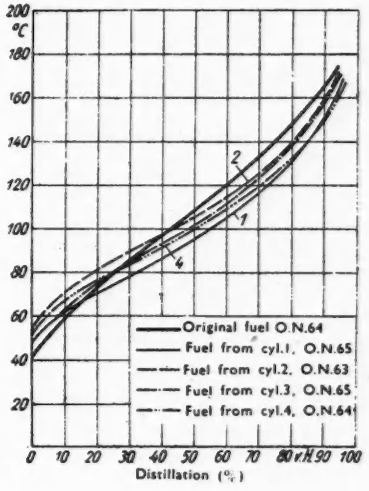

Fig. 3

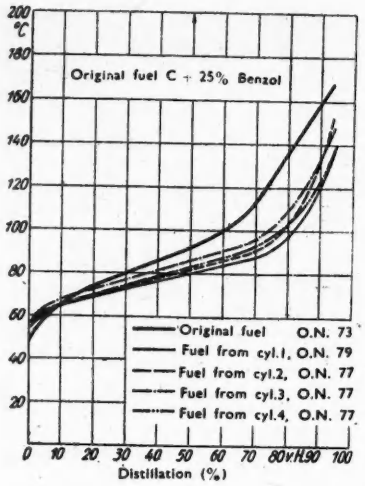

Fig. 4

Comparing the Octane numbers before and after condensation there is a difference of ±1 O.N., i.e., not of great importance. Fig. 3 shows the Engler distillation curves for the petrol fuel before and after the test, which does not show any appreciable alteration.

Next a similar series of tests was carried out, but this time the fuel used was a mixture of petrol (75%) and benzol (25%) of an Octane number of 73. This time the results were as follows:

TABLE V.

Cylinder	1	2	3	4
Quantity %	20	19	30	30
O.N.	79	77	77	77

A very marked fuel distribution appears in this case: While cylinders 1 and 2 receive some 20% of the total fuel charge, cylinders 3 and 4 receive about 30% each, a difference of 10% per two corresponding cylinders. It should be noted that it is again cylinders 3 and 4 that receive a greater fuel charge and hence a greater readiness to detonation. The Octane number determination following condensation reveals the startling fact that compared to the original figures there is an increase of about 3-4 O.N. in average. The assumption that the absorbing medium is responsible for this is reasonable. The examination of the distillation curve Fig. 4 also shows modification, in that the new curves lay in a lower temperature region, which is hardly the case with pure petrol. This would indicate that the petrol has actually reached the cylinders in the state as found after condensation and that the change has occurred during the passage through the induction pipes. With the petrol-benzol mixture the condensation might be responsible for the enrichment of benzol in the fuel mixture and thus for the apparent increase in the Octane number. On the other hand the argument could be brought forward that benzol in particular, is affected by the absorption medium causing the change in fuel characteristics.

Apart from the last mentioned consideration, one can generally state that the original fuel undergoes certain changes in the induction pipe, and that in addition to variable fuel distribution to the cylinders, the fuel itself differs from cylinder to cylinder thus causing differential combustion.

Although it was not possible to give a satisfactory explanation to all questions connected with detonation, nevertheless, the tests proved invaluable inasmuch as they have shown a number of factors affecting detonation and independent from fuel characteristics. The main issue of the tests is that there exists a complexity of factors affecting detonation which depend upon engine characteristics as well as upon fuel characteristics which cannot be ascertained by the usual fuel testing method in single cylinder engines.

This should, however, not be regarded as a verdict passed upon the usefulness of Octane number measurement: Fuel testing will certainly be needed in future to disclose fuel characteristics. However, the task will be only completed by determining subsequently the fuel characteristics which will suit best each particular type of engine. The engine characteristics themselves are due partly to mechanical features and partly inherent to multi-cylinder engines. Therefore, further development should include fuel testing in multi-cylinder engines, the possibility of which is afforded by the use of electro-acoustical detonation measuring apparatus.

ELECTRICAL DRIVES FOR WIDE SPEED RANGES

By G. A. CALDWELL and W. H. FORMHALS, Westinghouse El. and Man. Co. (From *Electrical Engineering*, Vol. 61, No. 2, February, 1942, p. 54/6, Transactions).

A NEW regulating device, a rotating regulator called a Rototrol is described, which gives a speed range of as wide as 120 to 1 or more when combined with a conventional variable voltage system (Ward Leonard system). The use of such a drive eliminates elaborate gear-change mechanism, clutches, and so forth and at the same time gives a more flexible control scheme with the complete speed range under the control of the operator without leaving the work or stopping the machine.

The conventional variable voltage system may be used for speed ranges in excess of 6 to 1 with 20 to 1 about the maximum range obtained by combination of motor-field and generator voltage control. The increase in speed range has been accomplished by widening the range of voltage control, the range in field control remaining not more than 4 to 1 and preferably only 2 to 1. Therefore, this type of drive is best suited to a load which has constant torque characteristics. The machine tool industry has many applications of this type. Most of the machine tools have constant torque characteristics as the load consists mostly of overcoming friction of the moving parts. With the wide speed range drive, the speeds required are always immediately available to the operator.

To develop a satisfactory wide-range variable-voltage drive it has been necessary to compensate for residual voltage of the generator and for the IR drop of the system.

Most commercial generators have a residual voltage of between 3 and 4%. However, it is desirable to extend the no load speed range beyond 25 to 1. Therefore, arrangements have to be made to overcome the residual voltage, which is a function of the previous

magnetic history of the generator. The equipment used to overcome residual, must be able to determine the actual conditions which exist.

Furthermore, some arrangement must be made to increase the applied voltage by the amount of the IR drop as the load is applied so that the induced voltage and, therefore, the speed of the motor will remain constant. It has been found that a rotating regulator or regulating generator is satisfactory for this particular function and has been widely applied.

This type of rotating regulator was first developed for elevators, and a large installation was made in Radio City in 1934. Since that time, the Rototrol has been used in many industrial applications as variable voltage planer drives, paper mill drives, electric shovels and skip hoists. It looks the same as a standard D.C. generator and is usually mounted as a unit of the variable voltage motor generator set (Fig. 1). Where a very great voltage range is required, and where the response should be quick and accurate, it has been found desirable to incorporate in the rotating regulator only the regulating functions which are desired, and to supply the normal excitation from some other source.

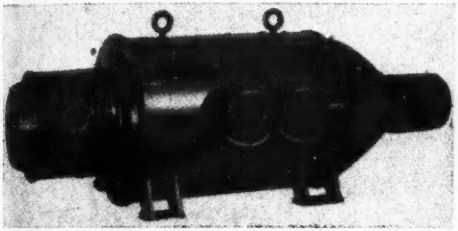

Fig. 1. Typical variable-voltage motor-generator set showing the units used in a wide-speed-range drive: This is a four-unit set with a main generator, exciter, and regulating generator (on the right-hand side) driven by a squirrel-cage induction moror.

A Wheatstone bridge circuit, shown in Fig. 2, is used for the supply of the regulating current to the field of the generator. Generator fields GF1 and GF2 are identical as are regulator fields RF1 and RF2. Resistors R1 and R2 are equal to each other and to the sum of the resistances of a generator and a regulator field. Thus all four legs of the bridge are of the same resistance and a balanced bridge results. If the exciter voltage applied alone to points A and C circulates Ia amperes in each leg AB and CD and if the regulator armature voltage applied alone to points B and D circulates Ib amperes in each leg Ab and CD, then when the two voltages are applied together, they will circulate in each leg AB and CD a current equal to the algebraic sum of Ia and Ib. Thus the use of a balanced bridge circuit permits complete independence of the excitation and regulating currents even though they have common paths in the field circuits of the generator.

In the schematic diagram of Fig. 2 the equipment required for a wide-speed-range feed equipment for a machine tool is shown, for the purpose of simplicity many control elements not required for this discussion being omitted. The circuit is basically a variable voltage system except for the addition of the regulating generator and its associated circuits. The generator differential field GF3 and its conductor BR are a part of the variable voltage scheme which prevents creeping in the "off" position and are not involved in obtaining wide speed range.

If the "forward" directional contactors are closed, a current Ia will flow from the exciter through the generator field rheostat and through the generator fields GF1 and GF2 in the two branches ABC and ADC. The generator will produce a voltage across its armature and thus across the motor armature, which will run at the speed determined by the field strength and the voltage applied, assuming no load and thus no current and no IR drop in the armature circuit.

The current Ia flowing in the regulator fields RF1 and RF2 will set up a magnetomotive force in the regulator which will circulate a current Ib in the direction so as to strengthen the fields of the generator and regulator in the bridge circuit. This magnetomotive force is balanced by the magnetomotive force of field RF3 which is connected so as to be differential to RF1 and RF2. Its strength is adjusted by resistor R5 so that at this condition of operation its ampere-turns are equal in magnitude to the ampere-turns of RF1 and RF2. Thus the fields in the bridge circuit get a cue as to the voltage which is desired and the field across the armature circuit measures the actual voltage which is obtained. Since at no load the speed of the motor is determined by its applied voltage, these two regulator field circuits compare actual speed with desired speed. If the calibration of the fields has been made at the point being described, then the resultant regulator magnetomotive force is zero and no voltage is present across the armature terminals and thus the regulating current Ib is zero.

If, however, the condition of operation being described is not at the calibration point but at some other value of speed, and that, due to shape of the saturation

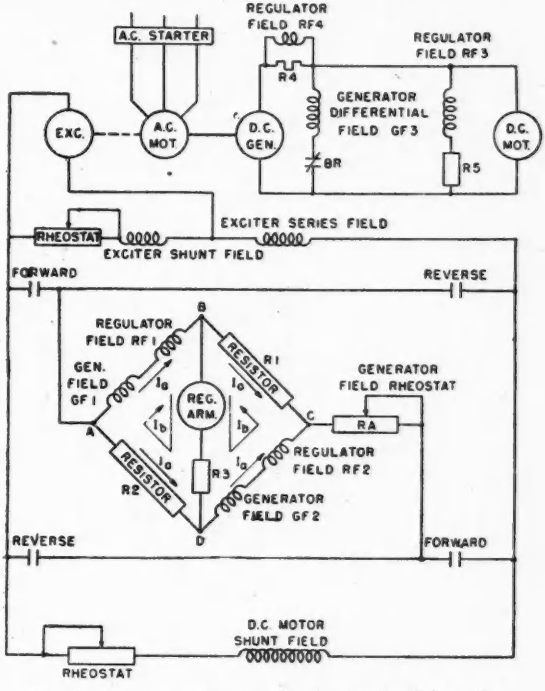

Fig. 2. Schematic diagram of main circuits of the wide-speed-range drive.

curve or to the effect of the hysteresis loop of the generator, the voltage generated is not as great as it should be to give the motor speed desired, then the differential ampere-turns in RF3 are not so great as the cumulative ampere-turns in RF1 and RF2, and a current Ib will circulate in the direction shown in Fig. 2, increasing the actual generator field current. Thus the generator voltage will increase to the value it should have.

To maintain this regulating current at the necessary value, the constants of the circuit consisting of the regulator armature, the resistances of the bridge circuit and the regulator fields FR1 and RF2 must be such as to make the circuit self-energizing. This can be done by adjusting resistor R3 so that the field characteristic line of the combined effect of fields will be coincident with the air-gap line of the no-load saturation curve of the regulator generator for those fields alone. Thus the regulator will force enough regulating current Ib through the generator fields until the proper operating point is reached. At this time the ampere-turns due to the current from the exciter Ia in the fields RF1 and and RF2 will be balanced by the ampere-turns in field RF3 due to the proper voltage across the armature of the generator, and the regulator current Ib through RF1 and RF2 will just maintain the current Ia.

The no-load speed of the motor will always be made to agree with the value desired by the setting of the generator rheostat. If mechanical load is put on the motor, it will slow down. A stable point of operation occurs, when the drop in speed and counter electromotive force is just sufficient to circulate the current required. To bring back the speed to the no-load speed, it is necessary to raise the generator voltage by the amount of the IR drop. This is done by the regulator by adding on its magnetic structure another field RF4 which is connected in the armature circuit so as to produce cumulative ampere-turns. By proper adjustment of R4, this field can cause the regulator to correct almost perfectly for IR drop and armature distortion of the motor over a wide range of load, thus giving a very flat speed-load curve.

Other conditions than load tending to change the speed of the motor may occur, as burning or shifting of generator brushes, or varying values of residual magnetism in the variable-voltage generator. Such conditions, however, are corrected by the regulator.

Fig. 3 shows the speed-load characteristics of a 7½

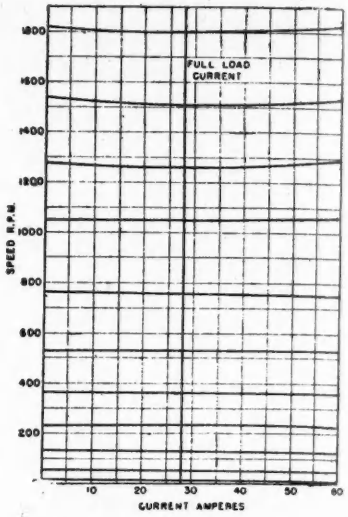

Fig. 3. Speed regulation curves covering a range from 15 to 1,800 r.p.m. (Maximum speed regulation at any speed is less than 5 per cent.).

horse-power machine tool feed equipment using a regulating generator such as just described. These curves show the regulation of the motor to double full-load current over a range from 15 r.p.m. to 1800 r.p.m. or a speed range of 120 to 1. Of this range speeds up to approximately 1000 r.p.m. are obtained by variable-voltage control, and from 1000 to 1800 r.p.m. by motor-field control. The change in speed due to application of load is negligible. There is no tendency for the motor to stall even when the speed has been reduced to 1/60th by voltage control. At light loads at this speed the voltage required is less than the residual voltage of the generator. The regulator, however, causes a reversal of current in the fields of the generator and thus bucks the voltage down to that required to get the speed called for.

IMPROVEMENTS IN LIGHTNING ARRESTERS

At a meeting of the Association Suisse des Electriciens on June 21st, 1941, the large Swiss electric manufacturing companies presented reports on recent improvements in lightning arresters they are manufacturing. Two of these reports are abstracted in the following.

LIGHTNING ARRESTERS FOR EXTRA HIGH VOLTAGES AND VERY HIGH DISCHARGE CURRENTS

By CH. DEGOUMOIS, Baden. (From *Bulletin Association Suisse des Electriciens*, Vol. XXXII, No. 25, December, 1941, p. 692-95).

LIGHTNING arresters should be of simple design and should not include any moving parts, which need periodical inspection and maintenance. The essential part of most modern arresters is the voltage dependent resistence (resistance having non-linear characteristics). When arresters for extra high voltages containing such resistances and air gaps are built up from several elements as shown in Fig. 1, it has been found suitable to use grading rings in order to achieve a uniform distribution of the voltage over the arresters.

Lightning arresters for extra high voltages should be able to discharge very high currents. The resistance during the discharge of these currents should be as low as possible, in order to avoid a high voltage drop and a high voltage at the terminal of the arrester. The company has designed two new types of arresters for a maximum discharge current of 50,000 amp.

(a) Arrester with voltage dependent resistances and expulsion tube.

Fig. 2 shows an arrester for a voltage of 15 kV, which consists of a variable resistance R, two spark gaps E_1 and E_2 and an expulsion tube. The value of the resistance R has been lowered in comparison with other types of arresters, which consist of a voltage dependent

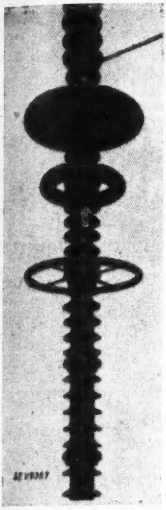

Fig. 1. Lightning arrester for 150 kV. Rated discharge current 10,000 A, maximum discharge current 100,000 A.

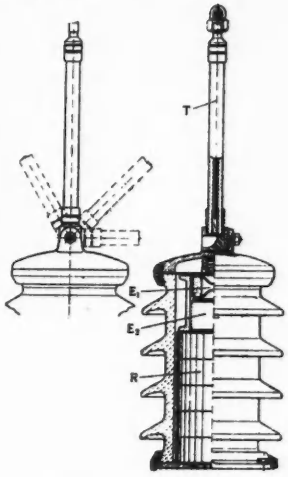

Fig. 2. Arrester with expulsion tube. T Expulsion tube, E_1 Main gap, E_2 Multiple gap, R Voltage dependent resistance.

resistance and one gap only. In consequence of the lower value of the resistance the 50 cycle follow current attains higher values, and it becomes necessary to provide something for its interruption. Therefore, an expulsion tube has been added of the design such as used successfully for many years as a lightning arrester. Interruption is achieved in these tubes by the sudden expansion of the gases produced by vaporisation of a thin layer of the insulating material of the tube. The material of the tubes is quickly consumed by frequent discharges, when used without a resistance in series. This disadvantage does not occur with the resistance R in series with the tube, which limits the follow current to a few hundred amperes. It was a further weakness of the expulsion tubes of the previous design, that the voltage at which discharge starts depends on the duration of the excess voltage. By a suitable design the new expulsion tube has become nearly independent of the duration of the excess voltage (Fig. 2, curve 2).

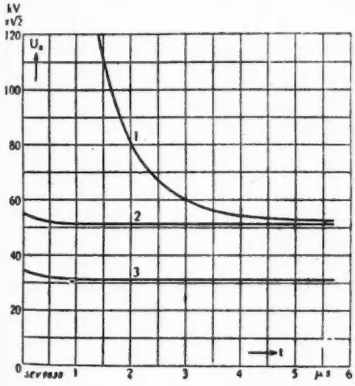

Fig. 3. Relation between the voltage Va, at which discharge starts and the time up to the beginning of the discharge.

1. Expulsion gap of usual design,
2. 15 kV arrester of the design shown in Fig. 2.
3. 11 kV arrester of the design shown in Fig. 4.

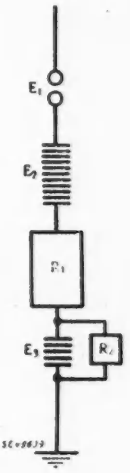

Fig. 4

Schematic diagram of the cascade arrester.

E_1 Main gap

E_2 and E_3 Multiple gaps

R_1 and R_2 Voltage dependent resistance.

(b) Arrester with cascade extinction.

This arrester contains only elements, resistances and spark gaps, which have been used in former designs of arresters with voltage dependent resistances. But a new combination (Fig. 3) is used. The discharge first bridges the gaps E_1 and E_2 and flows through the resistances R_1 and R_2. When the current becomes very high the gap E_3 is bridged and the resistance R_2 is shunted. Extinction first occurs at E_2. In consequence R_2 is inserted again in the circuit. Then the current is interrupted definitely at gap E_2.

An oscillogram is shown of a test with a discharge current of 33,500 A, the maximum current which could be produced in the laboratory in Olton-Gösgen of the "Commission d'études pour les hautes tensions." Another oscillogram shows that the follow current in a test with a 50-cycle system was interrupted within 1/4 of a cycle.

RESULTS OF RECENT DEVELOPMENTS IN LIGHTNING ARRESTERS

By A. GANTENBEIN, Zürich-Örlikon.

(From *Bulletin Association Suisse des Electriciens*, Vol XXXII, No. 25, 17th December, 1941, p. 695-99).

THE Maschinenfabrik Örlikon has improved the design of two essential elements of lightning arresters, the voltage dependent resistance and the interrupter of the power follow current.

1. Voltage Dependent Resistance.

The well known behaviour of these resistances is characterised by Fig. 1. A good resistance shows a small loop as for example curve b. The voltage dependent resistances consist of carborundum, that is crystals

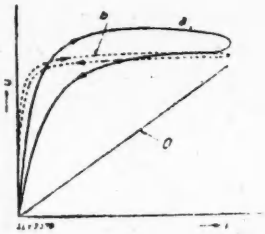

Fig. 1

Current voltage curve of a voltage dependent resistance : curve a great hysteresis loop, curve b Ideal curve,

o Ohmic resistance,

u Voltage across the resistance,

i Discharge current.

Fig. 2. Cathode ray oscillogram of a discharge of 70,000 amp. of 11 μs time to half value of wave tail.

of carbon silicide SiC, mixed with some binding material and burned like a ceramic product. Various explanations have been proposed for the peculiar behaviour of these resistances, one based on the phenomenon of the cathode fall, another on the negative characteristic of the little arcs burning in the pores between the carborundum crystals ; and a third due to Müller-Hillebrand assumes cold emission of electrons. The tests of the Maschinenfabrik Örlikon show that none of these theories is correct.

It has been found that the characteristic of the resistances of the usual type is not changed either when they are put under a pressure of air of 25 kg/cm² (about 350 lbs. per sq. in.) or when the pores between the carborundum crystals were filled with an insulating material. This shows that the dependability of the resistance is not caused by arcs in the pores of the material. From these experiments there resulted an unexpected improvement. The resistance capable of discharging a surge current of 1,600 amperes peak and 30 μs (time to half value of wave tail) when not impregnated and under normal pressure of air is transformed, when impregnated or put under pressure, into resistance for 20,000 amperes and the same tail length. Tests have been made with the maximum discharge of 70,000 amperes and 11 μs (time to half value of wave tail) which can be produced with the test plant of the Association Suisse des Electriciens (Fig. 2).

The following explanation is given for the variation of the resistances. The carbon silicide has a strong inclination to oxidise, even at normal temperature. Therefore, the crystals are covered with a very thin film of oxide of silicon, SiO_2. These quartz films prevent the passage of a current, as quartz is a good insulator at normal temperature. Carbon silicide belongs to the class of conductors, the resistivity of which decreases with a rise in temperature. If a voltage is applied across the resistance, the oxide films first prevent the passage of the current. But at a certain field strength the thin films become conductive or are pierced. It has not yet been elucidated if this flow of current is produced by an emission of electrons, similar to the process of thermo-emission, or by a flow of ions developing at higher temperature. In any case the points of contact between the crystals heat very quickly and become incandescent. Furthermore, it has been found that the hysteresis loop of these resistances is caused by the thermal sluggishness of the carbon silicide crystals.

There is yet another way of explaining the behaviour of the resistances. The crystals are covered with films of different thickness. The higher the voltage the more crystals participate in the transport of the current.

It has been found that impregnation considerably improved the stability of the resistances. In a duration test a discharge of 18,000 to 19,000 amperes and 30 μs to half value of wave tail was sent 200 times through a resistance without changing its characteristic.

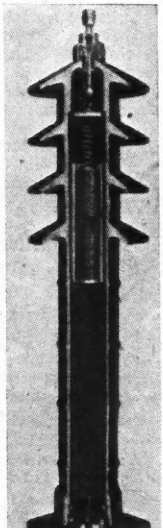

Fig. 3

Lightning arrester with self-extinguishing gap.

(a) main gap,

(b) tube which produces the pressure gas and extinguishes the arc

(c) Voltage dependent resistance.

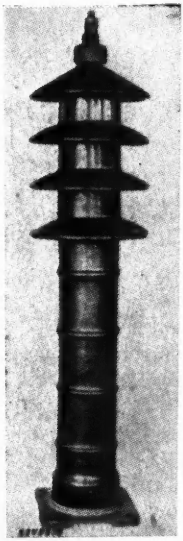

Fig. 4

Lightning arrester with pressure gas extinction tube.

(a) main gap,

(b) tube which produces the pressure gas and extinguishes the arc.

(c) Voltage dependent resistance.

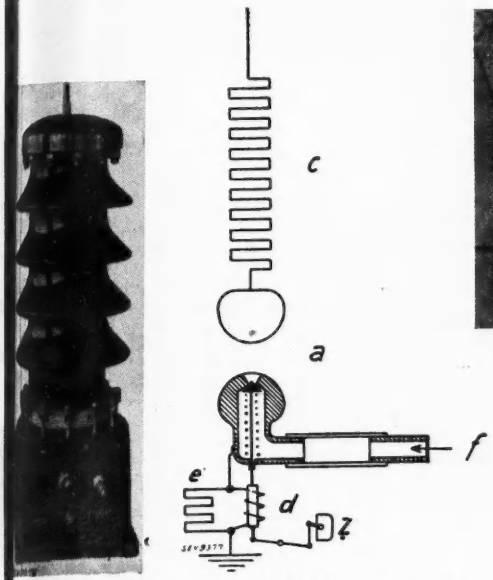

Fig. 5. Lightning arrester for 50 kV, provided with pressure gas from outside. a gap, c voltage dependent resistance, d valve with electromagnet, e voltage dependent resistance shunting the coil of the magnet, f inlet for the gas under pressure, z counter which registers the discharges.

2. Interruption of the Follow Current.

The usual type of arrester has a self-interrupting gap, which consists of a great number of discs and extinguishes the power follow-current after the surge has been discharged. Fig. 3 shows a typical design. The follow-current is interrupted by the discs with safety so long as it does not exceed a certain value. The nominal discharge current of an arrester has to be fixed according to the capacity of the gap to interrupt the power follow-current. When the current exceeds the capacity of the gap, the discs may be damaged by the arc or be unable to interrupt the current. Therefore, in order to make full use of the improvement of the resistances, two new designs using pneumatic gas blast interruption of the current have been developed.

(a) Arresters, in which the pressure gas is produced by the arc. Fig. 4 shows the principle of this design.

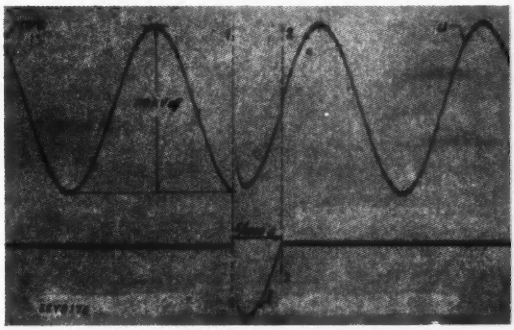

Fig. 6. Oscillogram of a discharge through an arrester with a pressure gas extinguishing gap : u voltage across the arrester, 110 kVeff., i follow current, 1 commencement of discharge, 2 extinction of the follow current.

The interruption of the power current is achieved by the pressure produced by the arc in an extinction tube. The current is interrupted at the first zero point when a heavy discharge passes the tube.

(b) Arresters, which are provided with gas pressure from outside.

Air under pressure of approximately 7 atmospheres is used for the interruption. In many new plants compressed air is used for various purposes, so that no special compressor plant for the arresters will be necessary. Where no air pressure is used for other purposes, a cylinder of compressed air may be provided for the arresters, a very small quantity of air (2–3 liter at working pressure for one interruption) being necessary. Fig. 5 shows this type of arrester. The resistance is placed in the upper part of the insulator, whereas the lower part and the base contains the valve and the counter. The valve is opened by a small electromagnet. The arc is extinguished within half a cycle. Fig. 6 shows an extinction in a 110 kV arrester in less than 5/1000 sec. The follow-current does not exceed a few hundred amperes. The counter registers each discharge. This arrester is especially suited for plants where even a direct stroke should not cause any damage to the arrester, or where very sensitive apparatus are to be protected. Even a direct stroke does not damage the simple air gap, which is capable of discharging very heavy strokes.

The great advantage of the extinction of the arc by gas under pressure is the higher follow-current which may be allowed, so that arresters with lower resistances may be used in plants which have a low level of insulation.

SINGLE-POLE FAULT CLEARING FOR GREATER STABILITY

By J. E. Hobson, Illinois Inst. of Technology, and H. N. Muller, Jr., Westinghouse Elec. & Man. Co.
(From *Westinghouse Engineer*, Vol. 2, No. 1, February, 1942, p. 23/5).

On a 50-mile section of a 138 kV system of the Public Service Company of Indiana a breaker and a relay system have been installed recently which permit clearing transient single line-to-ground faults by opening only the breaker pole connected to the faulted phase and reclosing rapidly. If the fault has cleared, the line remains connected ; if it has not, all three phases are permanently disconnected. Greater transient stability is attained by this system.

Stability Limit on the Rise.

Usually, the limiting factor in considering system stability is the transient rather than the steady state stability limit. Since long means have been sought to improve the performance of power systems during transient disturbances. During earlier years, attention was particularly focused on improvements attainable by better design characteristics of machines and transformers, bussing arrangements, location of intermediate

switching points, and design of the transmission line itself.

As it is not economical to design lines so that faults will never occur, it is important to minimize their effect on the connected system so that there is no interruption in service. In the last decade high speed for relays and circuit breakers have become practical and extensively applied. The use of reclosing breakers has materially improved system performance by minimizing the duration of transmission-line disturbances. Reclosing is particularly advantageous on a single circuit transmission line connecting two systems. But the clearing of the fault and the reclosing of the line has to be so rapid, that the two systems do not drift far enough apart to cause loss of synchronism. Reclosing in multi-circuit lines can be considered as an alternative to the construction of additional parallel circuits to obtain a higher transient stability limit, and can, therefore, result in large savings in capital investment.

The foregoing discussion has assumed simultaneous tripping and reclosing of all three circuit breaker poles, and is known as gang-operated or three-pole reclosing. Where high speed reclosing is applied to line sections having sources of power at both ends, simultaneous operation of the circuit breakers at both ends of the transmission line is essential, otherwise the time of interruption of the service is not used as far as possible for arc de-ionization.

The time that a line can remain open without loss of stability is a matter of cycles rather than seconds. Commercial breakers are available to-day with reclosing times (measured from the time the trip coil is energized until the breaker has opened and reclosed) of 35 and 20 cycles at 138 kV. Another factor of importance is the actual de-ionizing time of the arc. If the breaker is reclosed before the arc path has been de-ionized, the fault will restrike. Approximate data of the minimum reclosing time permissible under average conditions without the re-establishment of the arc are given in Table I.

TABLE I.—TYPICAL ARC DE-IONIZING TIMES.

Nominal System Voltage (kV)	De-ionizing Time for 95% of Faults (Cycles on 60-Cycle Basis)	Minimum Permissible Reclosing Time with 8-Cycle Breakers	Mirimum Permissible Reclosing Time with 5-Cycle Breakers
23	4	12	9
46	5	13	10
69	6	14	11
115	8.5	16.5	13.5
138	10	18	15
161	13	21	18
230	18	26	23

However, even employing high speed relays and breakers and operating these breakers at the highest reclosing speeds, practical cases will arrive, in which the desired power can't be transmitted without loss of stability during fault conditions. Since a high percentage of all high voltage transmission line faults are single line-to-ground faults, single-pole reclosing of circuit breakers is a step towards raising the transient power limits. By opening only the breaker pole connected with the faulty phase, and reclosing this pole after the fault has cleared, the transient stability limit is raised over that permissible with gang-operation for the same reclosing time, because considerable power may be transmitted over the two sound phases, while the faulty phase is isolated. Slower reclosing is possible than under three-pole operation. Hence, in high voltage systems, usually above 138 kV, when the three-pole reclosing time necessary to maintain stability may be less than that required for arc de-ionization, single-pole reclosing permits slower speeds, providing sufficient time for the arc to clear and still maintain stability conditions.

The actual gain in the transient stability limit attained with single-pole operation is shown in Table II. The figures relate to an assumed single station feeding a high voltage line terminating in a very large system, assumed to have infinite inertia. Stability is easily attained, if single-pole reclosing is used; but is not possible with the speeds of 3-pole reclosing circuit breakers commercially available at present.

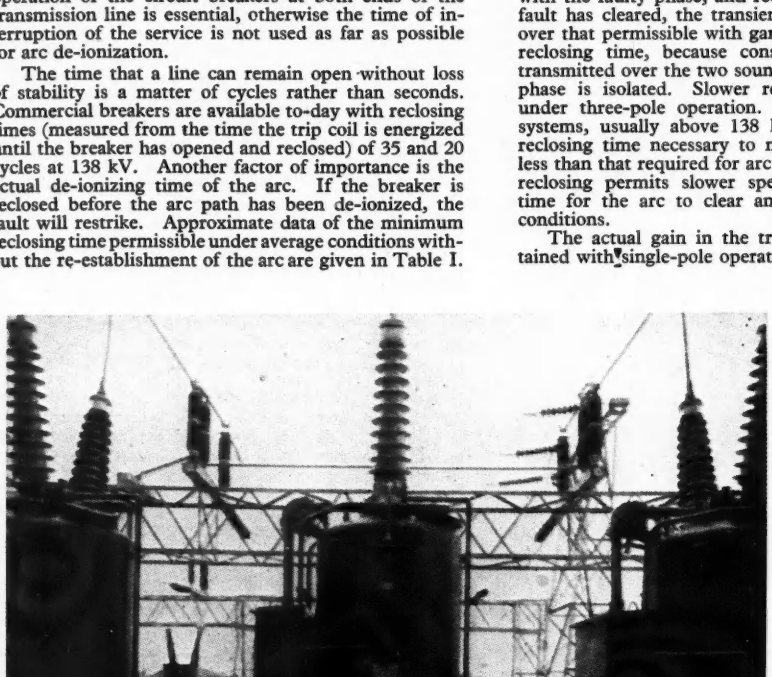

Fig. 1. There is no mechanical linkage between the operating mechanism of three 135 kV circuit breakers in the Newcastle Indiana Substation. Each breaker is equipped with a single-pole reclosing mechanism.

TABLE II.—TYPICAL COMPARISON OF TRANSMISSION POWER LIMITS IN A HYPOTHETICAL SYSTEM USING SINGLE-POLE AND GANG-OPERATED RECLOSING.

Total Reclosing Time Cycles	Per Unit Power Single-Pole Reclosing	Gang-Operated Reclosing
0	1.9	1.9
10	1.77	1.6
20	1.6	1.3
30	1.52	1.08
40	1.47	0.95

Application.

The first high voltage line equipped with single-pole reclosing breakers is the 50-mile Lenore-Newcastle line of the Public Service Company of Indiana. Its operating record since installation in March, 1941, and numerous field tests have proved conclusively the satisfactory operation of the scheme. The 138 kV line forms an interconnection of the system mentioned before with the Indiana section of the American Gas and Electric System. It was found necessary to equip the line with high-speed reclosing breakers, to keep interruptions to the load by transient instability at an absolute minimum. Power limits were calculated for gang-operated and single-pole reclosing. Table III. shows that during a single line-to-ground fault, 35 cycle single-pole reclosing offers higher transient power limits than 20 cycles gang-operated reclosing. 35 cycle single-pole has been chosen, as single line-to-ground faults are expected to occur more frequently than other faults and the increased cost of 20 cycle single-pole reclosing were not considered to be justified by the gain in power limit. The new relaying problem connected with single-pole reclosing, how to indicate which phase is faulted, has found a perfect solution, based on the phase-angle relation of the sequence components of the fault current. During a single line-to-ground fault, the negative and zero-sequence currents for the faulted phase are in phase, but the negative and zero-sequence components for the remaining two unfaulted phases differ in position by 120 degrees. The negative- and zero-sequence currents for each phase are segregated by suitable filters and applied to one element of a three element relay. Thus, when the fault is on, say, phase A only, the element A in the relay carries sequence components that are in phase. This element closes contacts and initiates the breaker operation. In the B and C elements the currents are not in phase and there is not enough torque to close the contacts. All relaying is controlled by carrier-current apparatus to permit simultaneous operation of the breakers at the two ends of the line. Single line-to-ground faults cause the breaker pole connected to the faulted phase at each end of the line to be tripped and reclosed. If the fault persists after reclosure, all three breaker poles are tripped and locked out. All breaker poles are tripped and locked out for all faults involving more than one conductor. Reclosing for faults on 2 or 3 poles was not considered necessary until transmitted power becomes higher.

Single-pole reclosing can be compared to the result achieved with the ground-fault neutralizer in that its salient advantage applies for single line-to-ground faults. Compared with ground-fault neutralizers single-pole reclosing saves the cost of neutralizers and permits the use of grounded-neutral transformers and lightning arresters so that better lightning protection of equipment connected to the transmission system is attained. However, during single line-to-ground faults single-pole reclosing involves unbalances, and as not much power can be transmitted during a line-to-ground fault condition as can be transmitted with neutralizers. During faults involving more than one phase, the reclosing provides a possibility of maintaining stability not enjoyed by the neutralizer system.

Two principal objections have been offered to the use of single-pole reclosing, namely, the possibility of telephone interference created by the flow of the current during the period of reclosure, and the possibility of false ground-relay operation in adjacent line sections caused by the circulation of ground current during the de-energized period. These difficulties were not encountered in the Lenore-Newcastle installation. It may be anticipated, that neither factor will be objectionable in most contemplated installations, since the ground-current resulting from the open phase is small and persists only for a short time. The disturbance to other ground relaying in the system is quite small, if good ground sources are available at both ends of the faulted section.

Tests.

Extensive field tests have been made on the system of the Public Service Company of Indiana. The results were exceedingly satisfactory in regard to reclosing equipment, relays, and the function of the new relay system. Typical results of the performance are: The Newcastle breaker interrupted 1300 ampere in 6 cycles after initiation of the fault and four cycles after the trip circuit was energized. The line remained de-energized nineteen cycles before reclosure, giving a reclosing time of 23 cycles. The Lenore breaker has a reclosing time averaging about 29 cycles, well under the nominal 35 cycles.

During one test the total Newcastle load, 40,000 kW, was supplied over the test line, with all paralleling ties open. No disturbance was noted at Newcastle or other points of the system and the oscillograms revealed that very little swinging of the Newcastle condensers or other connected machines occurred.

TABLE III.—CALCULATED TRANSIENT POWER LIMITS FOR THE LENORE-NEWCASTLE LINE FOR SINGLE-POLE AND THREE-POLE RECLOSING, AT 20 AND 35 CYCLES, USING 8-CYCLE BREAKERS WITH CARRIER-CURRENT RELAYING.

Item	Type of Fault	Breaker Operation Reclosing Time	Type of Reclosing	Comparative Transient Power Limits Megawatts	% *
1		35	Gang	74.5	100
2	Single line-to-ground	20	„	95.8	129
3		35	Single-pole	105.9	142
4		20		116.8	157
5		35	Gang	71.1	100
6	Double line-to-ground	20	„	91.1	128
7		35	Single-pole	81.3	114
8		20	„	97.3	137
9	Three-Phase	35	Gang	70.4	100
10		20	„	90.1	128

* Transient power limit obtained with 35-cycle, gang-operated breakers taken as 100 per cent for each type of fault.

FRICTIONAL PROPERTIES OF RUBBER

(From *Technical News Bulletin*, Washington, No. 300, April, 1942, p. 26).

THE results of an extensive laboratory study of the coefficient of friction of rubber, made by Frank L. Roth, Raymond L. Driscoll, and William L. Holt, has been published in the April, 1942, issue of the *Journal of Research*.

Most previous investigations have dealt with specific rubber products, such as tyres and belting, and the experimental conditions have been those under which the products are commonly used. In the present investigation, it was possible to employ a relatively wide range of experimental conditions and to control the compositions and surface conditions of the specimens and the tracks. The principal factors considered were speed and slide, roughness of sliding surfaces, pressure of one surface on the other, size of specimens, cleanliness of sliding surfaces, and composition of the rubber.

The following results were obtained:

1. When a clean rubber specimen is towed at a constant speed of 10^{-3} cm/sec. or more along a smooth track, the friction increases, reaching a constant equilibrium value only after several centimeters, of slide; correspondingly, when the specimen is allowed to slide down an inclined track under a constant load, the speed decreases to its equilibrium value. When a specimen is towed at a speed appreciably less than 10^{-3} cm/sec. the friction decreases to its equilibrium value; correspondingly, a specimen will continue to slide down an incline after the angle of incline is decreased to a value less than the angle of repose.

2. The equilibrium coefficient of friction increases markedly with speed—the values varying from about 1 at speeds of the order of 10^{-4} cm/sec. to more than 4 at speeds of about 5 cm/sec. The occurrence of vibrations of the specimens prevented observations at speeds much over 5 cm/sec. The softer rubber compounds vibrated at even lower speeds.

3. The equilibrium coefficients of friction for very low sliding speeds are less than the coefficient of static friction, but at speeds of 10^{-3} cm/sec. or greater the dynamic coefficients are greater.

4. Except for speeds appreciably below 10^{-3} cm/sec., the rougher the sliding surfaces the lower are the observed coefficients.

5. The coefficients of friction for a rubber compound are not greatly dependent on the compounding ingredients so long as these ingredients do not bloom out on the sliding surface. The presence of materials such as bloom or talc on the surfaces decreases the values of the observed coefficients.

RECENT DEVELOPMENTS IN PLASTICS

(From *Technical News Bulletin*, Washington, No. 300, April, 1942, pp. 25-26).

DEVELOPMENTS in plastics during 1941 are reviewed by G. M. Kline in the second annual edition of *The Progress of Science*, a publication of the Grolier Society.

Five important applications of plastics in bomber and pursuit planes were developed, namely: Transparent methacrylate resin in nose sections, gun turrets, observation hatches, and tail empennage; radio-antenna mast assembly moulded of phenol-formaldehyde composition containing macerated-fabric filler; fluorescent instrument panels fabricated of laminated plastics; an aileron control quadrant moulded of high-impact phenolic plastic; a moulded cabin ventilator which combines economy and speed in production with freedom from corrosion. Moulded plastics were also used in place of aluminium for structural parts in the 1941 model of the radiosonde.

Considerable attention was devoted to the utilization of certain natural products in extending the available supplies of moulding powders. Of primary interest were lignin, recovered as a by-product in the pulping of wood; soyabean protein, which has been used in conjunction with phenol-formaldehyde resin and wood flour in the moulding of automotive parts; and bagasse, the residual crushed fiber of sugar cane after the sugar-containing juice has been removed.

The outstanding development in moulding was in continuous extrusion, which provided plastics in decorative and structural shapes to replace aluminium, stainless steel, and other metals reserved for war purposes.

A special orientation process was perfected, capable of making continuous, rattan-like strips of greater strength, flexibility, and fatigue life than the natural product. The woven plastic strip is used as seat upholstery in cars and buses, theatres and public buildings, and replaces foreign supplies of such raw materials as rattan and reed, which were always expensive and now are practically unobtainable.

Extruded in the form of fine filaments, plastics are introducing some startling new effects in fields formerly reserved for textiles made from vegetable fibres. Plastic sheeting is also displacing textiles in garment bags, umbrella coverings, raincoats, shower curtains, hats, shoes, belts, suspenders, piece goods for curtains, and the like.

Synthetic resins became available in the U.S.A. during 1941 for use in water softening and purification, and other special applications involving separation of dissolved constituents from solutions by absorption.

One automobile manufacturer announced late in the year that his firm has constructed a car with a plastic body, but officials of the company made it plain that the plastic body is still in the experimental stage, and that its substitution for the conventional steel body is a long way off.

The successful operation of the rubber-bag moulding process for the fabrication of aircraft structures from synthetic resins and wood veneers in a number of plants in the United States has demonstrated that it is a practical method for producing airplanes, using materials and labour which are more readily available than those required for metal aircraft. Builders of the experimental craft anticipate that their moulding process will be adaptable for military transport gliders, commercial and private planes, and in larger sizes for commercial and troop-carrying transport airplanes. Resin-bonded plywood was also used extensively in military housing and in small boat construction.

Progress was reported in the application of plastics in many other industries, including electroplating and fluorescent lighting, and in making refrigerators, wire coverings, records, dentures, grinding wheels, chemical plant equipment, and lenses for gas masks and safety goggles.

LARGER ARC-WELDING ELECTRODES SPEED UP PRODUCTION

By H. O. WESTENDARP, Jr., General Electric Company. (From *General Electric Review*, Vol. 45, No. 5, May, 1942, pp. 267-268).

THE arc-welding process has demonstrated its effectiveness in speeding up the production of ships, tanks, guns, and innumerable other products. The problem now is to speed up arc welding; the problem of more work with less men must be solved.

The answer is: On those applications where work conditions permit, use larger diameter electrodes because they have a faster deposition rate in pounds per hour. Many jobs are being welded today with 5/32-in., or 3/16-in. diameter electrodes where a larger diameter electrode could be used to produce welds just as high in quality and at a decided increase in speed.

Based on the estimate of 200,000 arc-welding operators in industry, a study of the following data will indicate that if these operators could change to larger electrodes on one-quarter of their work the result would be equivalent to an immediate addition of 15,000 to 25,000 experienced operators to the welding industry.

Welding engineers have frequently advocated using larger electrodes for increased speed, and some progressive plants are now operating on this basis. Today, however, it is of greatest importance that this matter be investigated thoroughly by everyone engaged in welding. Careful analysis should determine:

1. The general classes of arc welding where this speed-up can be most effectively accomplished.
2. The specific applications in these classes where work conditions permit larger electrodes to be used.

The following considerations will serve as a guide in changing successfully from smaller to larger electrodes.

Position of Welding. A 3/16-in.diameter electrode is the largest size with which it is practical to do vertical or overhead welding. Larger electrodes require amperages which produce too much heat for proper control of metal in such welding; consequently the spatter loss would be excessive and the welds would be poor.

Fillet size. An increase from 5/32-in. diameter to 3/16-in. diameter electrode is not desirable for vertical fillet welds until the size of the fillet reaches 5/16-in. or greater. A 5/32-in. diameter electrode is accordingly preferable for making ¼-in. and smaller fillet welds in the vertical position. A 3/16-in. diameter electrode applied to these smaller size fillet welds results in surplus weld metal being deposited in the form of a convex bulge on the fillet which would not contribute to strength and would waste scarce electrode material.

TABLE II

Position of Welding	Change in Electrode Size	Increase in Deposition Rate
Vertical or Overhead	5/32" to 3/16"	33 per cent
Horizontal	3/16" to 1/4	50 " "
Flat	3/16" to 1/4	77 " "
"	1/4" to 5/16	43 " "
"	5/16" to 3/8*	18 " "

*Experience indicates that magnetic arc blow increases with the size of electrode and welding current. Therefore the ⅜ in. diameter electrode is generally limited to operation with alternating current only.

Plate thickness. In many applications the work is or can be successfully positioned for flat welding. In this, as in vertical or overhead positions, plate thickness will affect the maximum size of electrodes that can be regarded as practical to use. Generally, electrode diameters up to the plate thickness can be used. This is affected, however, by other conditions, such as fit-up, type of joints, etc. Larger than ⅜-in. diameter electrodes have not proved to be practical up to date.

Table I shows the speed-up that is possible in cases where work conditions permit change to larger electrodes. Table II shows rather startling increases in speed when considered on a percentage basis.

In addition to these savings, which are based on the difference in deposition rates of electrodes, larger electrodes reduce the number of times the operator has to stop welding in order to change electrodes. The time required for cleaning the crater and restriking the arc is also reduced. The number of changes required per pound of metal deposited for various sizes of electrodes are shown in Table III.

The following list of arc-welding applications and their corresponding electrode requirements will assist in determining where larger electrodes can be applied.

1. Field Welding: Ships, buildings, bridges, pipe lines, etc. Approximate electrode requirements: 85% all-position type, 15% flat type.

2. Shop Welding: General fabrication, tanks, gun mounts, ship subassembly work, machinery, etc. Approximate 65% flat type, 35% all-position type.

3. Shop Welding: Repetitive straightline production welding operations, axle housings, tank wheels, etc. 100% flat type or 100% all-position type.

4. Job Shop Welding: Miscellaneous small parts. Approximate 75% all-position type, 25% flat type. Classes (1) and (2) offer the greatest opportunity for speed-up. Applications in Class (1) should be studied to determine ways and means of increasing from 5/32-in. to 3/16-in. all-position type electrodes wherever work conditions permit. Applications in Class (2) should be studied to determine ways and means of increasing from 3/16-in. all-position type to ¼-in. horizontal type electrodes, wherever work conditions permit. This class also offers opportunity for increasing from 3/16-in. on up to ⅜-in. flat type electrodes.

TABLE I

Electrode Diameter	Typical Deposition Rate lb. per hour—100 per cent arc time			Type of Electrode
	Flat*	Horizontal*	Vertical*	
5/32"	2.9	2.7	2.4	All-position D-C (Reverse Polarity)
3/16	4.5	4.0	3.2	" " " "
1/4	8.0	6.0	..	Flat A-C or D-C (Straight Polarity)
5/16	11.5	..	..	" " " "
3/8	13.5	..	..	" " " "

* Current at proper value in all cases.

TABLE III

Electrode Size	Electrode Changes per lb Deposited
5/32" × 14" length	18
3/16 × 14 length	13
1/4 × 18 length	5
5/16 × 18 length	3
3/8 × 18 length	2

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TECHNICAL NEWS

Announcements in this section include News relating to British Firms, and on Equipment produced by British Manufacturers.

Available literature may be secured by addressing a request to the advertising department of "The Engineers' Digest," or by writing direct to the manufacturer and mentioning "The Engineers' Digest" as a source.

- NEW EQUIPMENT
- BOOKS AND CATALOGUES
- BUSINESS CHANGES
- PERSONAL
- NOTES

NEW EQUIPMENT

COOKE TOOLROOM MICROSCOPE.

A WELL-ILLUSTRATED pamphlet, describing the Cooke Toolroom Microscope (Cooke, Troughton & Simms Ltd., Kingsway North, York), has been published recently.

The instrument consists essentially of a massive cast iron stand carrying a worktable with movements in two directions at right angles and controlled by micrometer screws. The table also has a circular motion. The microscope, illumination apparatus, and projection attachment are mounted on a bracket inclinable about a horizontal axis in order that the screw thread, when under observation, may be viewed from a normal to the helix angle. The protractor and thread forms are engraved on glass and mounted in the focal plane of the eye-piece.

To the upper end of the microscope are attached units containing a protractor or screw thread forms, which are visible in the field of view and are superimposed over the image of the object under test. The general conception of the design is of a robust character, whilst vital parts, such as slides, are well shielded or otherwise protected.

The instrument is intended to serve as a comprehensive measuring apparatus in the factory and laboratory. The applications of the instrument may be broadly summarised as follows :

1. The determination of the relative position of two or more points on a piece of work by measuring the travel of the worktable necessary to transfer a second point to the position previously occupied by the first and so on.
2. Measurement of angles by successively setting a fiducial line, situated in the focal plane of the eye-piece, along each arm of the image of the angle and noting from a protractor scale the angle through which the fiducial line has been turned.
3. Comparison of thread forms with respect to outlines drawn on a glass plate situated at the focal plane of the microscope eye-piece and measurement of discrepancies therefrom.
4. Comparison of the enlarged projected image with a tracing drawn an exact number of times full size and affixed to the projection screen.

A price list is also included. (Price of pamphlet 6d).

HIGH TEMPERATURE ALLOY.

A BOOKLET published by the Cronite Foundry Co. Ltd., Lawrence Road, Tottenham, London, N.15, contains many illustrations of " Cronite " castings.

This igh temperature alloy is used where resistance to distortion is absolutely essential—such as for case-hardening vessels, for furnace jigs, for the enamelling trade for supporting special shape.—the entire absence of oxidation and strength at temperature making it possible to fuse all types of ware without any distortion.

The composition of this alloy is of chromium, tungsten, iron and other elements with nickel. A graph of particular interest shows the strength of the alloys at elevated temperatures. It is stated that oxide penetration after twenty thousand hours exposure of 1,000 degs. cent. remains only skin deep.

For service under reducing atmosphere conditions when sulphur is a destructive factor, a standard alloy is produced especially to resist such attack.

(1) Strength of correct welds is approximately 80% of tensile strength of casting.
(2) Casting contraction $\frac{1}{4}$" per foot.
(3) Machines readily with reduced speeds.

The following data are impressive :

Tensile strength at atmospheric temperature 35 to 40 tons per square inch.

Snap tensile strength at 1000° C.	12/15 tons sq. in.
Melting Point	1420° C.
Specific gravity	8.07.
Weight per cubic inch.	0.30 lbs.
Coefficient of expansion.	.000012 per °C.
Thermal conductivity c.g.s. units at room temperature	0.035.
Specific heat.	0.14.
Brinell hardness	180 to 200.

The qualities of this alloy are worth investigating by those requiring castings of heat resisting kinds.

1000-Ton Straightening Press.—A giant 1000-ton straightening press, standing 21 ft. high, has just been delivered by Watson-Stillman Co., Roselle, N.J., to the Penn Forge Co. It is used to straighten shafts from 12 in. to 18 in. in diam., and from 7 ft. to 60 ft. long.

For handling and positioning work, there are two sets of rollers, each set mounted on a hydraulic lifting ram, which in turn is mounted on a motor-driven carriage running on rails between the columns of the press. One set of rollers is motor-driven to rotate the work as required.

When the work is positioned, the lifting rams under the rollers lower it on to two bending blocks. Each bending block is independently motor-driven for separation adjustment from 2 ft. 3 in. to 18 ft.

Pressing speeds are 470 in. per min. advance, $15\frac{1}{2}$ in. per min. pressing, and 470 in. per min. return. The stroke is 38 in., opening 48 in., and space between columns 48 in. The press pump is a rotary piston oil type driven by a 50 H.P. motor.

CATALOGUES RECEIVED

Oxygen and Hydrogen Production.—A new edition of the pamphlet, " The Knowles Electrolytic Cell," describes in detail not only the well-established principles on which the cell is designed, but also the various improvements which have from time to time been made. Some historical notes on the development of the Knowles plant introduce the well-illustrated description of the special features of the electrolytic plant which has been

used for the last 30 years in great many countries all over the world. Free copies of the 28-page booklet may be obtained from The International Electrolytic Plant Co. Ltd., Sandycroft, Chester.

Practical Folder for Specifications and Data Sheets.—After nearly three years of war it is interesting to note how industry has been settled down to a routine which a year or two ago took people entirely out of their own element. Most of us are concerned with " getting on with the war " to the extent where little time is left for post-war planning. The knowledge, however, we are gaining now and the training received by war factory personnel will be of value in post-war development, and it should be utilized.

It is of great importance that information covering new materials, new applications, new methods, should be recorded so that when the war finishes we need not go through that dreadful period of total reorganization, but can swing straight into the production of material which will not be designed for its own destruction or the destruction of others.

With that end in mind, the Tungum Sales Co. Ltd., has just issued a practical folder which serves the useful purpose of accumulating data-sheets, five of which are already included in the folder, on the comparatively new composition of Aluminium-Nickel-Silicon Brass called Tungum Alloy. The folder itself gives general data including the physical and mechanical characteristics of the alloy, while the five data sheets published up to now give the special characteristics of the alloy together with the numerous possibilities of its application in the forms (rod and bar, wire, solid drawn tubing, castings, forgings, stampings, pressings, sheet and strip), in which it has been marketed.

Free copies of the useful folder may be obtained on application to the Tungum Sales Co. Ltd., Brandon House, Painswick Road, Cheltenham.

Extinguishing Incendiary Bombs.—If thermite incendiary bombs are tackled within a period of 20-40 seconds after falling they can in nearly every case be extinguished before any material damage is caused. Very good results have been obtained by using the R.S.Q. Extinguisher of The Nuswift Engineering Co. Ltd., of Elland, Yorkshire. These extinguishers contain water and a small sealed seamless copper container of compressed carbon dioxide. In operating a knob is struck which causes an internal sharp point to pierce a thin copper sealed cover in the container and releases the carbon dioxide into the water, giving at once a very high pressure highly atomised jet. A jet of this type of about 30 ft. long has proved to be most efficient in extinguishing the main combustion of the incendiary bomb as well as oil fires of the surface type, such as caused by oil bombs. The extinguishers here described can easily be carried by one person.

The British Institution of Radio Engineers held, on May 29th, its annual general meeting at the Federation of British Industries, Tothill Street, Westminster, S.W.1. During the year, nearly 380 new applications for membership had been considered, and from them over 200 new members had been elected. The annual report of the council was presented by the Chairman. For the years 1942/43 the following council elections were announced: A. L. Beedle, A. G. Eggington, L. Grinstead, S. A. Hurren, W. B. Medlam, W. E. Miller, Sir Arrol Moir, N. Partridge, J. A. Sargrove, W. D. Sell, G. A. W. Sowter, and W. W. Smith. An informal discussion on the subject of " Time Bases," in which many members took part, was introduced by O. S. Puckle, A.M.I.E.E.

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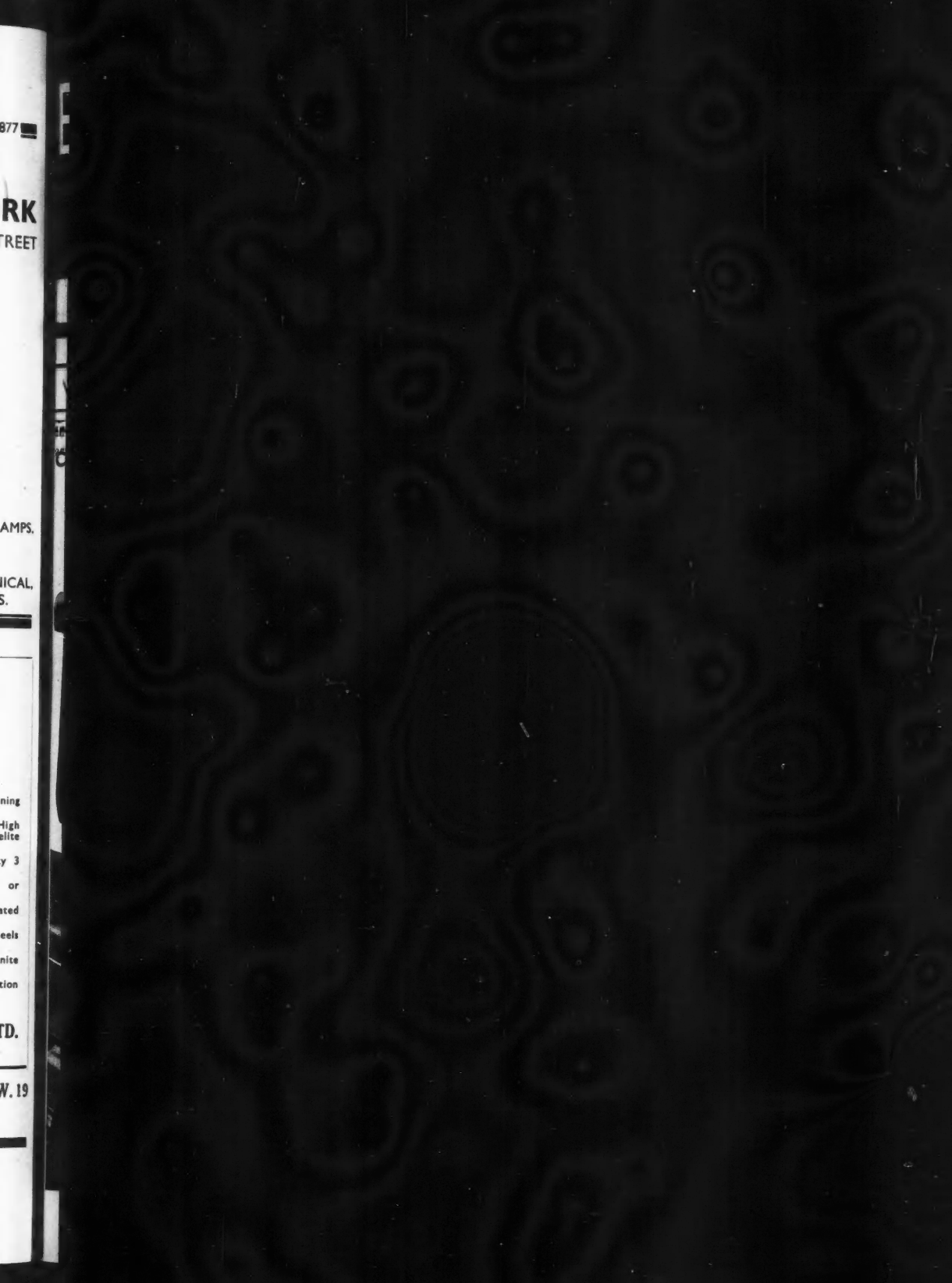
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